New Scientist

WEEKLY March 14–20, 2020

SPECIAL REPORT

THE FIGHT AGAINST CORONAVIRUS

- *Lessons from the latest data*
- Death rate recalculated
- *Italy in lockdown*
- The US failure to test
- *Africa's missing cases*
- A time for caution, not panic

RUNNING VS WALKING

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Prime Minister Jacinda Ardern with 2019 Ryman Prize winner Dr Michael Fehlings.

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This really is nothing like flu

Those downplaying the coronavirus ignore our lack of immunity and vaccines

FOR weeks now, the news has been dominated by the coronavirus. This is hardly surprising: it is an unprecedented global story with an unknown ending, featuring a new virus we don't yet fully understand. The planet's most populous nation shut down an entire province to try to contain it, and now there is an exponential uptick in cases worldwide.

It is also no wonder everyone is talking about the virus, given many people are worrying about the risks to themselves or their loved ones. No wonder, too, that inaccurate articles and even conspiracy theories are flourishing, and that warnings to be ready for self-isolation have led to panic-buying.

Inevitably perhaps – with the numbers of diagnosed cases currently still low in many countries – a backlash is under way. There is a view that the fatality rate will turn out to be tiny, that the new virus is no more noteworthy than flu and that the economic harm of containment measures doesn't justify the lives they could save. The media, meanwhile, is being accused of stoking panic in its reporting.

"The only people likely to have any immunity to the new coronavirus are those who have already had it"

But as Michael Leavitt, a former US secretary of health, put it last week: "Anything said in advance of a pandemic seems alarmist. After a pandemic begins, anything one has said or done is inadequate."

The best information now available suggests a fatality rate of around 0.7 per cent (see page 8), which means the covid-19 virus has the potential to kill a large number of people worldwide. The virus differs from flu in that there is no widespread immunity to it – the only people likely to have any are those who have already had it. What's more, unlike flu, we have no vaccines to give to those who are most at risk.

All this means that concern over the virus and considered action to delay its spread – such as meticulous hygiene and not taking your runny nose to work if you can avoid doing so – are fully justified. While much of China has seen a death rate of 0.7 per cent, the fatality rate was far higher in Wuhan, the city with the first cases, where hospitals were hit with many cases at once. Far from constituting "panic", precautionary action to tackle the virus is only sensible. ■

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FLAVIO LO SCALZO/REUTERS

A military presence in Milan's Piazza del Duomo, Italy

Italy in lockdown

With the second-highest number of coronavirus cases globally, Italy is taking dramatic steps to slow the spread, reports **Adam Vaughan**

ITALY has put the country's 60 million people on lockdown in the most drastic action taken outside China to tackle the spread of coronavirus. As of 10 March, the country had diagnosed more than 10,000 cases, second only to China. Prime Minister Giuseppe Conte has said Italy may not stop at the current restrictions and could use further "massive shock therapy".

Travel restrictions for northern Italy were first leaked on Saturday, causing panicked reactions before an official decree was published on Sunday. The measure, extended to the whole of Italy on Monday night, means people must limit travel except for work or medical reasons, or risk a three-month prison sentence or a €206 fine.

The travel ban is being enforced on roads by the Carabinieri (military police), while rail services, including night trains from Paris to Venice, have been cancelled. However, flight-tracking service Flightradar24 says that more than 250 flights departed from the five airports serving Milan and Venice on Monday, inside the area locked down on Sunday. A number of UK airlines have now cancelled all flights to and from Italy.

The Italian authorities said the draconian measures are necessary to slow the spread of the virus and relieve the burden on healthcare systems. A report in *The Guardian* said 733 people were in intensive care in the Lombardy region, one of the worst affected areas, but it only has about 500 public health intensive care beds.

"We are encouraged that Italy is taking aggressive measures to contain its epidemic. And we hope they prove effective in the coming days," said Tedros Adhanom Ghebreyesus, director general of the World Health Organization (WHO), in a press conference on Monday.

"The WHO is encouraged that Italy is taking aggressive measures to contain its epidemic"

The big question is whether they will work. Michael J. Ryan at the WHO says the measures could buy time for other areas to prepare. "Reducing the flow of potential infections in other areas may offer those [other] zones time to prepare and have a different outcome," he says.

Ryan compares the step with strict restrictions on movement in the Chinese province of Hubei and the city of Wuhan, where the virus originated. "The reason China could cope was it only had one Wuhan," he says. In Italy, he says the restrictions won't necessarily stop the disease moving, but it should delay the spread. Still, he cautions: "It's not a guarantee."

Despite some evidence from China, researchers say we don't know if the measures will work in Italy. "I think it's too early to say whether the travel restrictions will be effective, especially since people were moving in and out of the lockdown area before it was implemented," says Devi Sridhar at the University of Edinburgh, UK. But buying time for health services to cope is vital, she adds.

Trudie Lang at the University of Oxford says we will have to wait and see if Italy's efforts work. "Obviously, if you look at what we've achieved in China, the indications are that it had a strong impact," she says of the travel restrictions in Hubei.

Even if Italy's restrictions slow the spread of the virus, there are still questions over how long such strong action can be sustained. Italy has indicated the limits will be in place until 3 April.

What happens if the situation hasn't improved by then, asks Mark Woolhouse at the University of Edinburgh. "There is an important message here for any country considering imposing travel or movement restrictions in an attempt to slow the spread of covid-19: what is your exit strategy?" he said in a statement. ▮

Detection

Major testing issues in US

Delays and restrictions on who can be tested for the covid-19 virus in the US have raised the risk that it is spreading undetected, reports **Colin Barras**

IT IS more than seven weeks since the first case of coronavirus in the US, but according to one estimate, fewer than 2000 people across the country had been tested for the infection by 7 March. In contrast, reports suggest that more than 190,000 people have been checked in South Korea.

One reason for the low figure in the US lies in problems with the tests developed by the Centers for Disease Control and Prevention (CDC). Although it sent test kits out to state laboratories on 5 February, by 12 February it was clear there was a hitch with one reagent used in the test, and many state labs couldn't use the kits.

On its own, this might not have had such a severe impact on testing in the US because, says William Schaffner at Vanderbilt University in Tennessee, government labs can perform only a limited number of tests. "They have a finite capacity, not only in terms of reagents but in terms of personnel to process tests," he says. Instead, the US healthcare system relies on commercial companies to develop their own test kits and handle the bulk of the demand. "These larger commercial labs are more like factories," says Schaffner. "They can process many more specimens."

But commercial tests were also held up. US authorities declared the coronavirus outbreak a public health emergency on 31 January. In those circumstances, testing kits for the virus had to obtain "emergency use approval" from the US Food and Drug Administration. This further limited the ability to test for the virus in the US at precisely the time it became urgent and necessary to do so more widely.

The US Centers for Disease Control and Prevention's coronavirus test kit for labs

AP/SHUTTERSTOCK

The rules were eventually changed. From 29 February, companies were able to begin using their test kits without emergency use approval, providing they intended to apply for it. Commercial tests are now being made available.

"This will make it much easier for a physician to get a specimen tested," says Schaffner. However, even if they have health insurance, many people in the US may find they have to pay some insurance costs for private sector testing, which could act as a deterrent.

There are other problems. For weeks, the CDC recommended doctors test people only if they had symptoms and had recently travelled to China or been in contact with someone known to be infected, even though there were already notable outbreaks in other countries. It was only on 4 March that guidelines were relaxed to let anyone get tested with a doctor's approval – but reports suggest some people, including health professionals, were still being refused tests after this date.

There is also concern that, if demand for testing surges, critical test components could become scarce. "Demand is challenging our capacity to supply certain products," says Thomas Theuringer at QIAGEN, a firm based in Germany that produces some components of coronavirus tests. He says QIAGEN is ramping up production and hiring new staff to cope.

In the absence of adequate testing, the virus can spread undetected to form new outbreaks. On 8 March, Trevor Bedford at the Fred Hutchinson Cancer Research Center in Seattle published preliminary genetic tests on Twitter that appear to connect a coronavirus outbreak in Washington state with a case on the Grand Princess cruise ship, which docked in Oakland, California, on Monday. ▮

Fatalities

Why coronavirus death rate is so hard to pin down

HOW many of those infected by the coronavirus will die? It is still hard to say for sure, not least because the proportion of deaths will vary depending on local circumstances and how the outbreak is handled.

So what do we know? Last week, WHO director general Tedros Adhanom Ghebreyesus's take on this was widely reported. "Globally, about 3.4 per cent of reported covid-19 cases have died," he said.

That statement is correct, but was misunderstood by some as being the true death rate. Dividing the number of deaths by the number of reported cases doesn't reveal how many will die. This is because some of those recently confirmed to have the coronavirus and included in the reported case count might still die, pushing the true figure up. On the other hand, many people with mild symptoms might be going undiagnosed, pushing it down.

Last month, a study estimated that the fatality rate when infected people without symptoms are included in the case count is around 1 per cent, and this is still thought to be in the right ball park.

It is clear that some countries, including the US and Iran, are missing cases as so few people are being tested. South Korea, by contrast, had tested 190,000 people as of 9 March, with 7478 confirmed cases and 51 deaths.

This means 0.7 per cent of reported cases in South Korea have died so far, which matches what we have seen in China outside of Wuhan. If these places are detecting most cases, the fatality rate will not be much lower than this, though it could be higher if many recently infected people die.

> "The case fatality rate for covid-19 is not a fixed number and depends on many factors"

The fatality rate for covid-19 isn't fixed, and will vary based on many factors. Age is one (see opposite page), with the rate rising from around age 50 and reaching 15 per cent in over-80s, according to data from China. Countries like Niger, with many younger people, may fare better than Japan, where more than a quarter are aged over 65. ▮

Michael Le Page

Risk factors

Age, diabetes and heart disease linked to risk of death

Jessica Hamzelou

TWO small studies this week shed light on who may be most at risk of dying from covid-19, and how long it takes to develop symptoms.

Early on in the outbreak, two hospitals in Wuhan, China, were designated to treat people with the coronavirus. Bin Cao at Capital Medical University in Beijing and his colleagues have assessed all patients who had been discharged from or died at the hospitals by 31 January. They found that the average age was 56, and 62 per cent were men. Around half of those treated had underlying medical conditions, most often diabetes and high blood pressure (*The Lancet*, DOI: 10.1016/S0140-6736(20)30566-3).

62%
of study patients being treated for covid-19 were men

The average time from the onset of illness to discharge was 22 days. Of the 191 people treated, 54 died, on average, 18.5 days after symptoms began. Death was more likely in older people and those with diabetes or coronary heart disease.

"Poorer outcomes in older people may be due, in part, to the age-related weakening of the immune system and increased inflammation that could promote viral replication and more prolonged responses to inflammation," said co-author Zhibo Liu at Jinyintan Hospital, one of the designated hospitals.

A different study, of 181 cases of covid-19 covered in news reports, public health reports and press releases, has found that 97.5 per cent of those who develop symptoms do so within 11.5 days of infection. This suggests that 14-day quarantines will miss only about 1 per cent of cases. Half of those who show symptoms start to do so within the first 5.1 days (*Annals of Internal Medicine*, doi.org/dph3). ▮

Monitoring and surveillance

Number of cases across Africa remains low

Adam Vaughan

EXPERTS still don't know why so few cases of the new coronavirus have been reported in Africa, despite China being the continent's top trading partner and the continent having a population of 1.3 billion people.

As of 10 March, there were just 95 official cases on the continent, though two countries – Cameroon and Togo – recently reported their first cases. The highest number of official cases is in Egypt, which rose from two to 59 last weekend. Most cases in Africa have been imported not from China but from Europe.

Africa is of particular concern because of the fragility of some countries' health systems, and the fact that the continent already faces big public health issues, particularly malaria, tuberculosis and HIV.

The World Health Organization (WHO) has helped prepare African countries for the virus. In January, only Senegal and South Africa had labs that could test for it, but 37 countries now have testing capability.

Mary Stephen of the WHO, who is based in Brazzaville in the Republic of the Congo, says she believes the running tally of cases is accurate because more than 400 people have been tested for covid-19 across Africa so far. "I wouldn't say it's an underestimate," she says.

The lack of coronavirus-linked deaths on the continent implies there aren't yet big undetected outbreaks, says Mark Woolhouse at the University of Edinburgh, UK. "If there were major outbreaks, of the scale that Italy or Iran have had, anywhere in Africa, I would expect those deaths to be well above the radar by now."

KOLA SULAIMON/AFP VIA GETTY IMAGES

Nigeria's health minister Osagie Ehanire at a press briefing

Jimmy Whitworth at the London School of Hygiene and Tropical Medicine says one possible reason for the low numbers could be isolation measures implemented by countries. Four African countries have imposed quarantines on visitors from coronavirus hotspots.

More broadly, on the monitoring efforts to detect the virus at airports and other entry routes, Whitworth says "a lot's being done", citing coordination by the WHO and both the African and US Centers for Disease Control. Rwanda, for example, has recruited final year medical students to undertake screening at airports, says Woolhouse.

The WHO says most of the 37 countries in Africa with testing capacity have between 100 and 200 testing kits. Researchers think many more will probably be needed as cases spread, but that this is a start. "It is much better to have some than no capacity at all," says Woolhouse.

African countries are both vulnerable and potentially more resilient to the coronavirus. On the one hand, the population is much younger than in Europe and China. The median population age in the UK is 40.2 and in China it is 37, but this figure is 17.9 in Nigeria, Africa's most populous country. "If you look at the statistics from China, the people that have worse prognosis are the older people, not necessarily the young," says Stephen. The flip side is that health systems are generally more fragile in many African countries, she says.

The big risk is that fighting a coronavirus outbreak becomes a distraction from other diseases, including malaria and measles, says Woolhouse. He points to the 2014-16 Ebola outbreak, where many of the thousands of resulting deaths were due to resources being diverted away from other diseases. ▮

Drug development

The hunt for covid-19 drugs

Many drugs and vaccines are now being developed and tested

Debora MacKenzie

AS THE number of coronavirus cases escalates, a massive research and development effort is under way, with human trials planned.

What the thousands of people who already have the covid-19 virus would benefit from is a drug that can stop it replicating. To find what may do this, people are ransacking lists of existing drugs that could be repurposed with minimal further testing.

Leading the pack is remdesivir, an experimental antiviral drug now undergoing large trials in patients in China and the US, including 13 people who were on the Diamond Princess cruise ship.

It is hoped that the drug, which failed in trials against Ebola in 2014 but passed safety tests, can stop the covid-19 virus replicating by blocking a crucial enzyme. Its maker, US firm Gilead Sciences, is building manufacturing facilities ahead of trial results in April.

Trials are also planned for kaletra, a combination of two anti-HIV drugs that stops viral replication and has reportedly worked on covid-19 in China.

Chloroquine, an antimalarial drug that most malaria now resists, might also hold promise. Studies suggest that it stops the related SARS virus replicating and invading cells, and that it works against the covid-19 virus. Treatment guidelines in China now recommend two 500 milligram doses daily.

Another approach is to use proteins called monoclonal antibodies that target specific viruses for destruction by the immune system. Vir Biotechnology in the US has made monoclonal antibodies for the covid-19 virus for an experimental diagnostic test. It now plans, with Chinese firm WuXi Biologics, to test them as a treatment. US firm Regeneron is brewing similar antibodies.

A team at Imperial College London has used artificial intelligence to assess approved drugs for promising candidates, and identified a rheumatoid arthritis drug, baricitinib (*The Lancet*, doi.org/dph5). This blocks the pathway the covid-19 virus uses to invade cells, as well as interfering with interleukin-6, the signalling molecule that triggers the lethal runaway immune response that can kill in severe cases. An antibody called tocilizumab is already being used in China to block interleukin-6 in people with covid-19.

42 days

How quickly one firm was able to make enough vaccine for trials

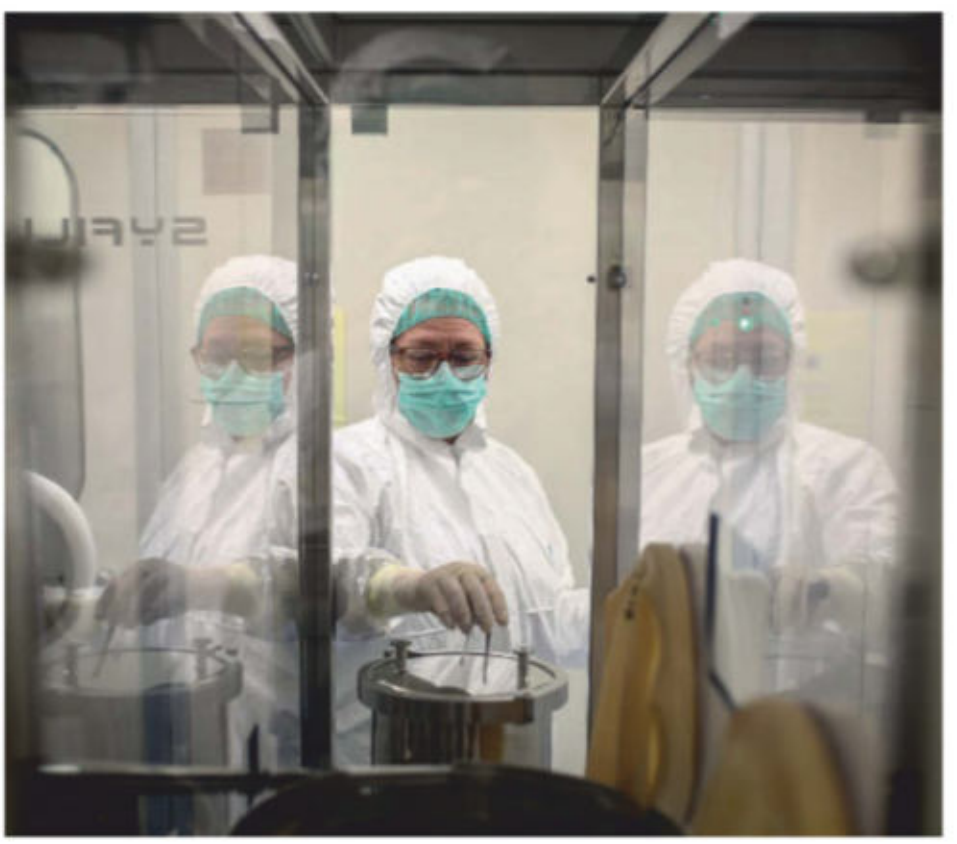
For people who don't catch the virus during this outbreak – and future generations – a vaccine will be needed. French firm Sanofi is working on hybridising the covid-19 virus with a harmless baculovirus already approved for its flu vaccine, which it can make in mass quantities to test if it works as a covid-19 vaccine.

The Coalition for Epidemic Preparedness Innovations (CEPI) is backing several other drug candidates. It was launched in 2017 by the Gates Foundation and several governments to develop vaccines for new diseases. "We were set up to respond to exactly this situation," says spokesperson Jodie Rogers.

CEPI plans to have at least one vaccine in human trials by May. If trials succeed, it plans to make "hundreds of millions of doses available" by early 2021.

This week, CEPI announced that it would back a vaccine developed by the University of Oxford that is made of Vaccinia virus, once used in smallpox vaccine, carrying an external spike protein from covid-19. The group will also support a vaccine from US firm Novavax made of "nanoparticles" of the spike protein plus an immune-stimulating chemical.

Many labs are working on drugs to prevent or fight infection with coronavirus



OLIVER BUNIC/BLOOMBERG VIA GETTY IMAGES

CEPI has already launched four other covid-19 projects. US firm Inovio had been working on a DNA vaccine for the related MERS virus, and says it had one for covid-19 just 3 hours after the gene sequence for the virus was published on 10 January. It plans clinical trials in April and to have a million doses by December, if the approach works.

DNA vaccines are rings of genetic material that enter our cells and make viral proteins that induce immunity. However, they have never been approved for humans for fear they might affect our own genes or induce damaging immune reactions.

Messenger RNA vaccines don't pose the same problems. CEPI is backing one from CureVac in Germany and another from Moderna in the US, which recently made enough vaccine for human safety trials in the record time of 42 days.

Supporters say that DNA or RNA vaccines, unlike some conventional vaccines, can't cause disease, are stable, cheap to mass-produce and effective in small doses – all boons in a pandemic emergency. By the time they are fully tested, however, covid-19 may no longer be an emergency. It may even be hard to find test subjects not already immune.

The coalition is also supporting more conventional vaccines, including a process to make viral proteins from the University of Queensland, Australia, and a viral protein vaccine from China's Clover Biopharmaceuticals plus an immune-boosting additive from British firm GSK. A further 48 proposals are still being considered. ■

Robotics

Hospital ward run by robots to spare staff from catching virus

Sarah O'Meara

A NEW hospital ward run entirely by robots has opened in Wuhan, China, in a bid to protect medical staff from contracting the coronavirus.

On 7 March, about 200 patients exhibiting early symptoms of covid-19 were ushered into the new ward, which is in a converted sports centre in Wuhan, the city where the outbreak started.

The robots deliver food, drinks and drugs to the patients, and keep the ward clean. Some have a humanoid head, arms and upper torso but a wheeled base, while others look more like a box on wheels. The machines can move around autonomously but are under the observation and control of staff outside the ward.

The trial is a partnership between CloudMinds, a Beijing-based robotics firm, and mobile operator China Mobile, along with Wuhan Wuchang Hospital, an institution at the heart of early efforts to contain the virus. The hospital's director Liu Zhiming died of the disease last month.

The ward was established as a human-run clinic, but has now been turned over to the robots after a week-long upgrade. Engineers mapped the ward and uploaded the information to a cloud server to help the robots navigate the area.

CloudMinds CEO Bill Huang says the ward will be a pilot case. "This is China's first-ever entirely robot-led ward and an opportunity to test the capability of the technology and how we work together," he says.

Robots will look after patients who aren't acutely ill but who need basic medical care. If they recover, they will be sent home. If their health problems become more acute, they will be transferred to the human-run hospital.

During their stay, patients wear bracelets fitted with sensors to measure their heart rates and temperatures. This information is displayed on a large screen outside the ward for doctors and nurses to access along with other health information. Medical staff can also use the screen to assign the robots their next task.

"The staff have a much better view of how things are going and can immediately find out if something isn't right. I think it's a very high-tech and new way of trying to run a hospital," says Huang.

Patients may also welcome the novelty, he says. "As we developed the plan, I talked to staff in the hospitals. They say the patients are very bored being isolated, so they love to see the robots."

Chenguang Yang at the Bristol Robotics Laboratory, UK, says this kind of experiment is promising but cautions that there may be difficulties. "There will be lots of people moving around in a hospital ward. It will be a major challenge for robots to work in such a dynamic place." ■

Robots are being trialled in a hospital in Wuhan, China

CLOUDMINDS

Analysis Virus strains

There are two types of the new coronavirus What does that mean? Jessica Hamzelou explains

TWO strains of the new coronavirus are spreading around the world, according to an analysis of about 100 cases. But the World Health Organization (WHO) insists "there is no evidence that the virus has been changing". So how many strains are there, and does it matter?

Viruses are always mutating, especially RNA viruses like this one, the covid-19 virus. When a person is infected with the coronavirus, it replicates in their respiratory tract. Every time it does, about half a dozen genetic mutations occur, says Ian Jones at the University of Reading, UK.

When Xiaolu Tang at Peking University in Beijing and his colleagues studied the viral genome taken from about 100 cases, they identified two types of the virus: 72 were considered to be the "L-type" and 29 were classed as "S-type".

The work also suggests that the L-type was derived from the older S-type. The first strain is likely to have emerged when the virus jumped from animals to humans. The second emerged soon after that, says the team. Both are involved in the current global outbreak. The L-type being more prevalent suggests that it is "more aggressive" than the S-type, the team says (*National Science Review*, doi.org/ggndzn).

"There do appear to be two different strains," says Ravinder Kanda at Oxford Brookes University in the UK. "[The L-type] might be more aggressive in transmitting itself, but we have no idea yet how these underlying genetic changes will relate to disease severity," she says.

"The virus is as it was when it originally emerged. There is no evidence it is getting worse"

The differences between the two identified strains are tiny. In fact, they can't really be considered to be separate "strains", says Jones. And many of the genetic differences won't affect the production of proteins, so won't change the way the virus works or the symptoms it causes, he says. One is not more deadly than the other.

"In all practical terms, the virus is as it was when it originally emerged," says Jones. "There's no evidence it is getting any worse."

This sentiment is echoed by the WHO. The study by Tang and colleagues only suggests there is some genetic diversity of the virus – it doesn't mean it is changing, a representative told *New Scientist*. ■

Technology

Liquid metal that floats on water could make flexible robots

Donna Lu

A LIQUID metal alloy that is less dense than water has been made by injecting the material with glass beads. It may hold promise for making lightweight exoskeletons or transformable robots.

Liquid alloys don't solidify at room temperature and are eutectic, meaning that they melt at a lower temperature than the individual melting points of the metals they are made from.

Jing Liu at Tsinghua University in China and his colleagues have created such a material by mixing pure gallium and indium to create an alloy with a melting point of 15.7°C.

To decrease its density, they stirred tiny glass bubbles filled with air into the liquid. The loose beads, which were no more than 75 micrometres in diameter, clustered together in the mixture. Oxygen mixes in with the liquid metal, which helps the glass beads stay suspended, says Liu.

15.7°C
The melting point of the gallium-indium alloy

The beads decreased the density of the alloy by up to 97 per cent without altering its other properties – it has high electrical conductivity and it can be shaped and deformed. These features make it ideal for making lightweight exoskeletons, or flexible robots that could transform as the temperature changes, says Liu.

Depending on the glass beads' size, the liquid's density varied between 0.45 grams per cubic centimetre – less than half that of water – and 2.01 grams per cubic centimetre (*Advanced Functional Materials*, doi.org/dpb5), which Liu says could help control the buoyancy of underwater devices. ▮

Field notes Fixing fatty livers

Treating organs outside the body Many donor livers have to be thrown away, but a crash course of intensive treatment could make them suitable for transplant, reports Clare Wilson

I AM face to face with a freshly removed pig's liver connected to a maze of tubing and sitting in a clear plastic tub. It doesn't look healthy – it is dull with a greyish-brown complexion. But then I am given permission to press a button and the machine the liver is connected to whirs into life.

The device, which effectively performs the function of a heart and lungs, was developed by Peter Friend and his colleagues at the University of Oxford and their spin-out firm OrganOx. It perfuses the liver with oxygenated blood warmed to body temperature, and the organ quickly starts to flush a dark reddy-brown and look glossier, even plumper.

These kinds of machines were invented to keep people alive while their heart was stopped for surgery, but smaller versions are now used to keep human organs going outside the body to aid in transplant operations. Such devices play a part in a few heart, liver and kidney transplants, both to extend the time an organ can remain safely out of the body and to help doctors judge if it is functioning well. "It's like taking it for a test drive," says Constantin Coussios of OrganOx.

Yet the researchers want to go further. Their first goal is to tackle an increasingly common problem, fatty liver disease. This occurs when the organ's cells accumulate too much fat. Although it can happen in people who are slim, it is more common in those who are overweight, affecting nine out of 10 people who are obese.

MARCUS HESSENBERG/BARCROFT MEDIA VIA GETTY IMAGES

There are too few donor organs to meet transplant demand

Depending on the disease's severity, transplanted fatty livers may not function as well as transplanted livers in good shape. With waistlines expanding, that means increasing numbers of donated livers have to be turned down. Of all livers rejected for transplant in the UK, half are declined because of fatty liver.

But what if we could get a liver to lose its fat while it is kept outside the body? Friend's team has developed a way to do this, effectively putting an isolated liver on a crash diet for two days.

This is achieved by using two chemicals that make cells release fat and then filtering out the resulting fat particles from the blood circulated to keep a liver alive. The chemicals, forskolin and L-carnitine, are commonly sold as weight loss supplements.

In 2018, the team showed that the approach makes livers lose fat, in a study that used 16 organs that had been donated for transplant but had been rejected due to their fattiness. The researchers' next step is to repeat the "de-fatting" method, this time with livers that have borderline fat levels and are destined to go into people. They hope to start the trial at the end of this year. "To my knowledge, it would be the first time a human organ has been treated for any disease while outside the body," says Friend.

Other groups are trying different approaches. Robert Porte at the University of Groningen in the Netherlands and his colleagues, for example, will try heating livers to 40°C to raise their metabolic rate and make them burn more fat. "It would be like causing a fever," says Porte.

Fatty liver isn't the only condition that could be treated outside the body. While an organ is isolated in this way, it may also be possible to dose it with cell or gene therapies that make it less prone to sparking an immune response in the recipient. Transplant recipients currently have to take immune-suppressing drugs for the rest of their lives, leaving them prone to infections and cancer. ▮

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The big interview

Palaeontology

A tiny skull in amber

New dinosaur species identified from 99-million-year-old remains

Layal Liverpool

"I WAS blown away when I first saw the skull, it's so well preserved and so damn weird," says Jingmai O'Connor at the Chinese Academy of Sciences. "I knew it was so rare."

This birdlike dinosaur was discovered in northern Myanmar and has been analysed by O'Connor and her colleagues. It is 99 million years old and the smallest dinosaur ever found from the Mesozoic era.

CT scans revealed that the creature, named *Oculudentavis* or "eye tooth bird", had bulging eyes and sharp teeth (*Nature*, DOI: 10.1038/s41586-020-2068-4). Its narrow eye sockets would only have let in limited light, suggesting it was most active during the day.

The skull measures just 1.4 centimetres across, indicating it may have been smaller than any bird living today, but the jaw shape suggests it had a powerful bite. "It was probably smaller than the bee hummingbird," says O'Connor.

LIDA XING

Climate change

Tropical forests may stop absorbing CO_2

SCIENTISTS have warned that the world must reduce carbon emissions to net zero sooner than 2050, after discovering that tropical forests are removing less and less CO_2 from the atmosphere.

Climate change models predict that forests in the Amazon and equatorial and West Africa will act as a sink for carbon emissions well into the second half of this century. But Simon Lewis at the University of Leeds, UK, and his colleagues found that the Amazon could be a net emitter of carbon in as little as 15 years. "It's grim, so grim. It's the most worrying paper I've written," says Lewis.

The researchers looked at ground surveys of 300,000 trees over 30 years in these regions, and found that CO_2 absorption in the Amazon has already shrunk significantly, with equatorial and West African forests set to follow.

Intact forests across these areas removed 6 per cent of humanity's CO_2 emissions in the 2010s, or around 25 billion tonnes of CO_2. This is down from around 46 billion tonnes, or 17 per cent, in the 1990s. This change was due to forests shrinking, the remaining trees growing less and so absorbing less CO_2, and the huge growth in carbon emissions from humans.

The researchers used these observations to model the future and found that while the Amazon could become a net source of carbon emissions by 2035, the tipping point for equatorial and West Africa was far enough in the future that they didn't project a date (*Nature*, doi.org/ggnd46).

In recent years, there have been calls to cut global emissions to net zero by 2050 to avoid temperature rises of more than 1.5°C. Yet this deadline is based on models that assume tropical forests will still be carbon sinks in the second half of this century. As this no longer seems likely, Lewis says we will "need faster and greater cuts to get to net zero" sooner than 2050.

2035

The year the Amazon could be a net source of carbon dioxide

Stopping deforestation, which has reached a 10-year high in Brazil, will also be key, because disrupted forests are more likely to dry out and release CO_2.

Erika Berengeur at the University of Oxford says this analysis provides a good estimate of tropical forests' carbon sinks, but their diminished capability to absorb CO_2 shouldn't be used as an excuse to chop them down.

She notes that the study only focuses on intact forests and that even though large areas of the Amazon have been disturbed by human activities, those parts still play a vital role in absorbing CO_2.

Adam Vaughan

Climate change

Journal retracts study blaming sun for climate change

Adam Vaughan

A PROMINENT scientific journal has retracted a study claiming that climate change was due to solar cycles rather than human activity.

Last year, *Scientific Reports* came under fire for publishing a paper that researchers said made elementary mistakes about how Earth moves around the sun.

Now the journal – published by Nature Research, which also has *Nature* in its stable of titles – has formally retracted the paper.

The withdrawn study had argued that the average global 1°C temperature rise since the pre-industrial period was due not to our greenhouse gas emissions but to the distance between Earth and the sun changing as the sun orbits the solar system's centre of mass. In a statement, *Scientific Reports* said that was inaccurate.

The journal said calculations show that the "Earth-sun distance varies over a timescale of a few centuries by substantially less than the amount reported in this article. As a result, the editors no longer have confidence in the conclusions presented."

Ken Rice at the University of Edinburgh, UK, says papers should be retracted only in extreme circumstances, but the errors warranted it here. "Solar system orbital dynamics is extremely well understood, and it wouldn't have taken much for the authors to have checked if their claims about the significance of the motion of the sun around the solar system barycentre were indeed correct," he says.

"This is sensible and a welcome move from the journal," says Gavin Schmidt at the NASA Goddard Institute for Space Studies in New York.

Valentina Zharkova at Northumbria University, UK, one of the study's authors, says the paper's retraction was unfair and the corrections made to it were minor. ▮

Cosmology

Neutrinos reigned in the early universe

Leah Crane

JUST after the big bang, neutrinos were king. These tiny particles interact with other matter so weakly that about 100 trillion of them pass through your body unnoticed every second, but they may have had huge effects on the structure of matter in the early universe.

In the first few thousand years of the cosmos, before the formation of galaxies or stars, small ripples of matter started to form, says Francis-Yan Cyr-Racine at the University of New Mexico. "The way those ripples form depends dramatically on how neutrinos behave."

Yu Liu at Shanghai Jiao Tong University in China and his team developed a new way to analyse the large-scale structure of the universe for the effects of neutrinos by scanning its density. They found that in the early universe, areas without much matter still contained neutrinos, and that large clumps of matter were a little blurry around the edges (arxiv.org/abs/2002.08846).

Liu suggests this is because neutrinos, even with their slight mass, pulled matter away from denser regions, slowing down the accumulation of matter and making the edges of those clumps less defined than they would otherwise have been.

We don't know the exact masses of neutrinos, but we know they are extremely light and so can move at nearly the speed of light. As other particles were starting to clump together in the early universe, neutrinos' speed and low interaction allowed them to continue zipping around without getting caught in the clumps.

"The way the ripples of matter formed depends dramatically on how neutrinos behave"

But their mass still attracted other matter. The locations where neutrinos dragged matter nearly 14 billion years ago guided where stars and galaxies would eventually form.

"At the time that structures begin to clump together and create density contrast, neutrinos tend to damp that clumping," says George Fuller at the University of California, San Diego. Not only does this effect elucidate how crucial neutrinos were, studying it further could help solve the mystery of neutrinos' mass, he says.

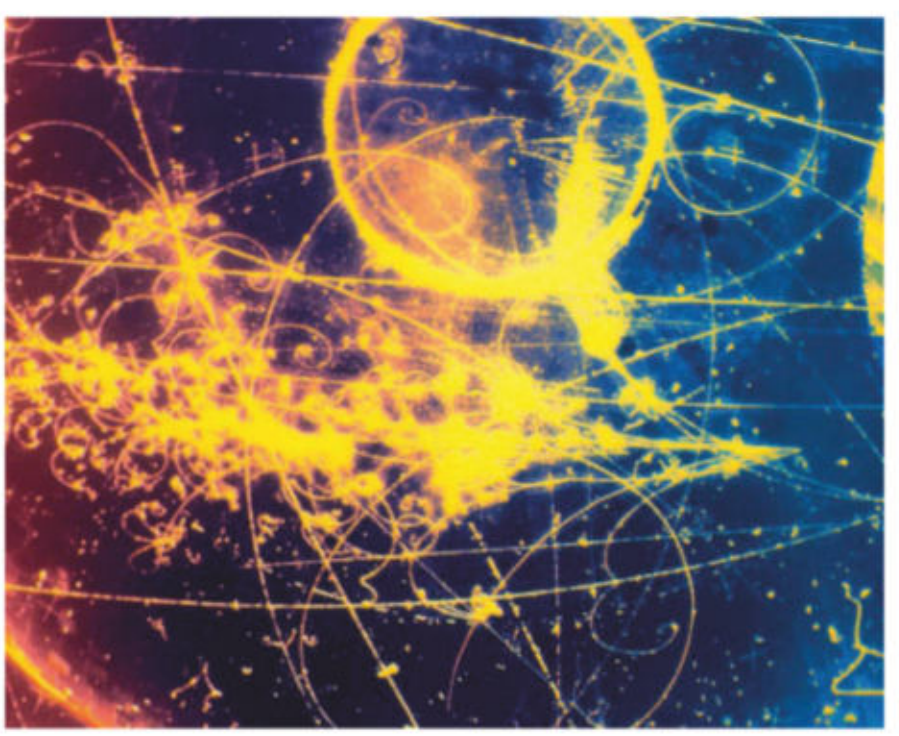
Neutrinos could help us solve another major mystery: the precise amount of lithium in the universe. Based on how much lithium we calculate was made in the big bang, we expect old stars to contain far more of this element than they do, and it isn't clear why it is missing.

Alexander Heger at Monash University in Australia and Stan Woosley at the University of California, Santa Cruz, tried to clear up this discrepancy by looking into the differences in how the earliest stars exploded and how stars do so now.

When a star explodes in a supernova, it releases high-energy neutrinos that can kick-start cascading nuclear reactions. The first stars would have been relatively compact, which means the neutrinos would have hit the stellar material much harder because it was closer to the exploding core.

The pair found that this high density and extra energy meant the neutrinos would kick off extremely efficient reactions, which should have produced more lithium in old stars than we see (arxiv.org/abs/2002.04749). "It does not solve the problem, it makes it worse," says Heger.

Much of the lithium – as well as some other elements – in the universe now may have been made by neutrinos in these sorts of supernovae, he says. ▮



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A bubble chamber can capture the paths of sneaky neutrinos

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Environment

Net-zero push may raise pollution

Some ways to meet UK carbon-free goal could end up polluting air, says leaked report

Adam Vaughan

A WIDESPREAD switch to burning hydrogen to heat UK homes to meet new climate targets risks releasing harmful nitrogen oxide (NO_x) pollution in urban areas, according to a leaked report obtained by *New Scientist*.

The report by air quality experts for the government's Department for Environment, Food and Rural Affairs (DEFRA) lays out pros and cons for pollution of the UK's new legal target of cutting carbon emissions to net zero by 2050.

Hydrogen, which is backed by industry and government advisers as a key fuel to replace natural gas to decarbonise heating, could lead to NO_x emissions if used in boilers in homes and businesses, it says.

"The use of hydrogen as a significant energy source for domestic and commercial space heating would potentially lead to NO_x emissions being concentrated in higher density population areas," the report says.

What's more, it says building large, clean-energy projects could also cause local air pollution to rise. Nuclear plants are cited as a concern due to long build times. For example, the number of trucks coming and going at Hinkley Point C, a nuclear power station being constructed in Somerset, is up 20 per cent since 2016.

However, the air quality experts say the shift to electric cars will bring "unambiguous benefits" by eliminating the release of one form of NO_x, toxic nitrogen dioxide (NO_2), which is mostly pumped out by diesel engines.

That said, they caution that particulate matter, which can lead to serious illness or death, will remain a problem unless there is a switch away from vehicles to more walking and cycling. This is because a lot of particulates come not from exhausts on modern cars, but from dust released by the tyres, brakes and road surfaces.

DBURKE/ALAMY

Air quality might be at risk as the UK moves to a low-carbon economy

The authors say that as buildings become more energy efficient, they must be designed to avoid accumulation of indoor air pollutants due to inadequate ventilation. However, well-designed building upgrades can avoid the risk. "Poor indoor air quality is by no means an inevitable consequence of energy efficiency," the report says.

Other measures for cutting carbon emissions from homes, such as district heating schemes, could also have a temporary negative effect on air quality because they may use polluting fuels such as biomass before later transitioning to cleaner sources.

> **"It is important to guard against the unintended consequences of our environmental policies"**

Growing more bioenergy crops also poses a potential threat for air quality, as some fast-growing plants can release volatile organic compounds (VOCs) into the air. These chemicals can lead to formation of ozone at ground level, which is another pollutant.

Even so, the researchers say that, overall, moving to net-zero carbon will create "major opportunities" for cleaner air. Attempts to clean up farming are largely seen as a universal good, with low-carbon efforts like manure management also cutting air pollutants, including NO_2 and ammonia.

Using hydrogen in the gas supply network would, despite the concerns over NO_x, "completely eliminate" VOCs such as ethane, propane and butane, which leak from pipes, according to the analysis. Another technology to clean up heating – heat pumps – is seen as "highly beneficial" for cutting both VOCs and NO_x.

More energy efficient homes should curb the use of wood-burning stoves, a rising source of air pollution in cities. And moves to far more renewable electricity generation will bring a range of air quality benefits, it adds.

The report is based on one scenario of how to get to net zero, provided by the UK government's climate adviser, the Committee on Climate Change. DEFRA didn't respond to requests for comment.

Robert Gross at the UK Energy Research Centre, who wasn't involved in the report, says it is important to guard against unintended consequences. For example, past policies promoted diesel cars to cut carbon emissions but inadvertently made other forms of air pollution worse.

While the impact of hydrogen boilers on air quality is worth looking at, he says it is unlikely that we should be "desperately worried" about it. "For the most part, the solutions we need to be moving to net zero involve moving away from combustion-based energy conversion altogether and therefore are quite likely to have beneficial local air quality implications," he says.

In response to the report, boiler maker Worcester Bosch said lab tests of its hydrogen boiler had found NO_x emissions were half those from a natural gas boiler. ■

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Global warming

Our carbon emissions made Australia's fires more likely

THE recent bush fires in Australia were made more likely by human-made climate change, an international team has found.

An analysis by World Weather Attribution (WWA), an international climate initiative, discovered that the weather conditions responsible for the fires were made at least 30 per cent more likely because of human-induced warming. Two climate phenomena, the Indian Ocean dipole and southern annular mode, were also found to have played a big role.

Debate has raged over the cause of the fires, with Australian prime minister Scott Morrison calling them business as usual, while misinformation campaigns blamed arson by green activists.

The WWA ran climate models of a world with and without human-made climate change to identify any effect on the bush fires. They didn't find humanity's fingerprint in monthly and annual drought records, but they did find one in a fire weather index, a measure of weather conditions, including temperature, wind and humidity, that make fire more or less likely.

Friederike Otto at the University of Oxford, part of the WWA team, says: "Because of climate change alone, we find at least a 30 per cent increase in the likelihood of these events to occur." But the true figure is likely much larger, she says, because the models underestimate the role of temperature rises.

The attribution analysis looked only at south-east Australia. Overall, the fires burned 19 million hectares and destroyed nearly 6000 buildings. Adam Vaughan

Solar system

Moon rocks do show trace of giant impact

WE HAVE found new evidence in moon rocks to support the leading hypothesis about our satellite's birth – that a Mars-sized object called Theia hit Earth 4.5 billion years ago in a giant impact.

If this idea is accurate, it would have involved debris being blasted into orbit around our planet which later fused to become the moon. As a result, we would expect the rocks on the moon to look like a mix of Earth and Theia, but samples from the moon show that oxygen isotope levels look a lot like those in Earth rock. So what happened to the bits of Theia?

Fresh light has been shed on this by Erick Cano at the University of New Mexico and his colleagues who have conducted a new analysis of lunar rocks. They were able to take more precise measurements than had been done previously, while also considering both the type of rock and where they were found – and discovered huge variation in oxygen isotope levels.

"While Earth rocks occupy a very narrow range of oxygen isotope compositions, the lunar samples demonstrated nearly three times that variability," says Cano. He says this had been overlooked in the past because rocks returned from the moon are in limited supply and researchers rarely get to analyse a lot of them.

The team found that the lunar rocks from the deepest parts of the moon showed the most variation in oxygen isotope levels compared with rocks from Earth (*Nature Astronomy*, DOI: 10.1038/s41561-020-0550-0). Cano says that these could be the most representative of Theia's original composition.

"This work is definitely a very big deal," says Sara Russell at the Natural History Museum in London. She says the findings give more support to the giant-impact idea. **Jason Arunn Murugesu**

Materials science

Gold-coated fabric could be safety boon

STRETCHABLE, light-emitting clothes made from fabric coated in gold could be a smart alternative to high-visibility gear – not to mention a bold fashion statement.

Tricia Carmichael at the University of Windsor, Canada, and her colleagues started with a fabric that is 87 per cent nylon and 13 per cent spandex. They added a very thin coating of gold to act as an electrode and send power to a light-emitting material (pictured) in a range of patterns.

THE CARMICHAEL LAB

The fabric as a whole is semi-transparent, so light can shine through it. Carmichael says it has big advantages over existing high-visibility gear, which relies on reflecting light from other sources.

But it will be a while before such light-emitting clothes hit the shops, as the current version requires an unfashionable battery pack about the size of a deck of cards. One alternative the researchers are looking at would be to harvest energy directly from the movement of the wearer's body (*Matter*, doi.org/dpbv).

"Having clothing that can light up without requiring an external light source would be valuable," says Clara Barker at the University of Oxford, but the team will need to look at durability, cost and battery life. "A heavy, poor lasting or unreliable battery will be a critical factor in the success of this technology," she says. **Layal Liverpool**

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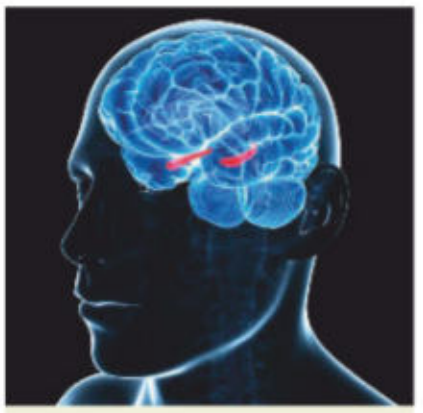
Really brief



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Time cells found in human brains

A type of brain cell that helps in the recall of the sequence and timing of events has been seen in humans for the first time (*bioRxiv*, doi.org/dpb4). Time cells are in the hippocampus (depicted above, in red), which is affected by early stages of Alzheimer's. Previously they had been seen in rats.

Smoking bans don't fully protect you

You can breathe in harmful tobacco fumes even in non-smoking indoor venues. Researchers at Yale University found tobacco chemicals in the air inside a non-smoking cinema that were probably released from the bodies and clothes of people who had smoked or been near smokers (*Science Advances*, doi.org/ggnd43).

NASA's next Mars rover gets a name

The rover on the Mars 2020 mission to be launched by NASA is now called Perseverance. Its name was suggested by a secondary school student in Virginia, and beat around 28,000 entries in a public contest. The rover is due to blast off in July and reach Mars in February 2021.

Archaeology

Ancient humans used out-dated tools

SKULL fragments found alongside different types of stone tools in Ethiopia are shedding light on the lifestyle of the ancient hominin *Homo erectus*.

Sileshi Semaw at the National Research Centre for Human Evolution in Spain and his team identified two *H. erectus* skulls at a site in Gona, Ethiopia.

One is 1.26 million years old and the other at least 1.5 million years old. They were found directly alongside various stone tools.

"This is good evidence that these hominins were the creators of those artefacts," says Michael Rogers at Southern Connecticut State University, who was part of the team that made the find.

H. erectus evolved around 2 million years ago in Africa and was one of the first species we know of from our genus.

Compared with earlier hominins, members of this species had relatively large brains and were adept tool-makers. They invented the so-called Acheulean tools, which include teardrop-shaped hand axes. This technology superseded older, simpler Oldowan tools, which are sharp-edged stone flakes.

Hand axes are a multipurpose tool. It was thought that once these had been invented, *H. erectus* stopped using the more primitive tools.

The discoveries at Gona dispel this notion, showing that both types of tool were used at the same time (*Science Advances*, doi.org/dpbx). This finding suggests *H. erectus* was more behaviourally flexible than we thought. **Alison George**

Space

JSC/NASA

Lettuce grown in orbit is delicious in a cheeseburger

LETTUCE is just as nutritious when grown in space as when grown on Earth, suggesting astronauts could one day produce their own food.

Gioia Massa and her colleagues at NASA's Kennedy Space Center in Florida analysed three batches of lettuce grown on the International Space Station (pictured) between 2014 and 2016. They compared the space crop with lettuce (*Lactuca sativa*) grown on Earth under similar conditions, controlling for relative humidity, carbon dioxide concentration and temperature.

By culturing the bacteria found on the lettuce and analysing DNA, they found that there were more microorganisms on the lettuce from the space station than on those grown on Earth. Massa says this was expected. On the other hand, the levels of nutrients in both types of lettuce were very similar, which was a surprise (*Frontiers*, doi.org/dpbw).

The researchers decided to use a red romaine cultivar for the experiment because its seeds germinate reliably and because most people don't actually mind eating lettuce.

According to Massa, the astronauts think the lettuce is delicious and they have tried it with tacos and cheeseburgers. JAM

Obesity

Bacteria may leak from gut into body

BACTERIAL DNA has been found in the blood, liver and fat of people who are obese, showing that either fragments of bacteria or entire live bacteria could be leaking from their guts.

In people who are obese the intestinal barrier is more fragile, says André Marette at the Québec Heart and Lung Research Institute in Canada. If bacteria get through this, they could contribute to the development of diabetes by causing inflammation in organs.

To investigate, Marette and his team analysed samples of blood, liver and fat tissue from people having surgery for weight loss. They took many precautions to rule out bacterial contamination.

They were surprised to find a wide range of bacterial DNA in the samples, including from harmful strains (*Nature Metabolism*, DOI: 10.1038/s42255-020-0178-9).

They can't say whether the DNA came from living or dead bacteria but think the most likely source is gut bacteria. Living bacteria can cause serious infections, but none of the people showed signs of this.

If the leaking of bacteria does play a part in the development of diabetes, it might be possible to develop new treatments for it, Marette says. **Michael Le Page**

Justice

Treatment on trial

Efforts to prevent prisoners from reoffending are rarely backed by scientific evidence, reports **Clare Wilson**

UK POLITICIANS are considering new measures to combat domestic violence. Many elements of the government's proposed Domestic Abuse Bill have been welcomed by campaigners, but it also includes a plan for those convicted of such offences to be regularly monitored after release with lie detector tests.

Lie detectors, also known as polygraph machines, measure changes in people's pulse, sweating rate and other indicators, but they are notoriously inaccurate so it isn't clear they can prevent reoffending.

The issue goes to the heart of a broader problem in the criminal justice systems of many nations. Very few crimes result in people spending the rest of their lives in prison, so sooner or later they are released – and our methods for attempting to prevent repeat offences lack scientific evidence.

Prison treatment programmes based on psychological techniques are designed to cut reoffending, but it is unclear if they work. They may achieve nothing, wasting money, or even make it more likely that people will reoffend.

Such programmes have been around for decades. Early attempts were based on Freudian-style psychoanalysis, where people talk about their childhood.

"We are trying to get offenders to stop and think instead of going straight to violence"

By the 1980s, these were being replaced with cognitive behavioural therapy (CBT), a form of counselling that aims to change people's thinking patterns.

CBT is perhaps best known as a treatment for emotional problems like depression and anxiety. There is good evidence to show it can help with these conditions, but changing complex behavioural patterns such as criminal offending is another matter.

MARJORIE KAMYS COTERA/BOB DAEMMRICH PHOTOGRAPHY/ALAMY

How can we ensure people avoid crime once released?

At first, CBT treatments in prisons were primarily aimed at sex offenders, but now they are used to tackle other crimes such as domestic violence. Programmes seek to help people understand the thinking processes and choices that preceded their criminal behaviour. They might include techniques for improving relationships with others and managing anger. "We are trying to get them to stop and think instead of going straight to violence," says Richard Taylor, a forensic psychiatrist in London.

Unfortunately, we don't know if this approach works. It isn't that there have been no studies of these programmes, it is just that most are very poor quality, says Robert Forde, a former UK forensic psychologist and author of *Bad Psychology: How forensic psychology left science behind*.

For example, many studies are too small to be useful, some looking at just tens of people. Or instead of measuring reoffending rates, they look at a proxy, such as impulsiveness reported through a questionnaire. After six months of therapy, the offender may know very well what answers they are supposed to give, says Forde.

Even studies that avoid these problems aren't usually gold-standard randomised trials, but simply compare people who got the intervention with ones who didn't, without ensuring they had similar characteristics.

When one Canadian group tried to summarise the findings of all studies of a certain kind of sex offender treatment, they had to discard 105 out of 130 papers for failing to use robust enough methods. This analysis did find that treatment programmes were linked with lower reoffending rates, but other analyses disagree, including one from the Cochrane Collaboration in 2012, which looked only at randomised trials of sex offender treatments, and found no effect.

William Marshall, a retired psychiatrist and one of the early pioneers of CBT for sex offenders, believes it does work when done properly, but that key aspects are often dropped to cut costs. "You have to have people who know what they're doing," he says.

Raising reoffending

Alarm bells rang in the UK after a large study of a CBT programme for sex offenders found it actually seemed to slightly raise reoffending rates. Out of nearly 16,000 men, 10 per cent of those who went through it carried out a sexual offence in the eight years after their release, compared with 8 per cent who hadn't taken part. It wasn't a randomised trial, but the researchers did carefully match those in the two groups to ensure fair comparison.

One explanation for the apparent rise is that the group therapy sessions involved could have helped to normalise the acts being discussed, according to a Ministry of Justice report. "When stories are shared, their behaviour may not be seen as wrong or different," said the authors. "At worst, contacts and sources associated with sexual offending may be shared."

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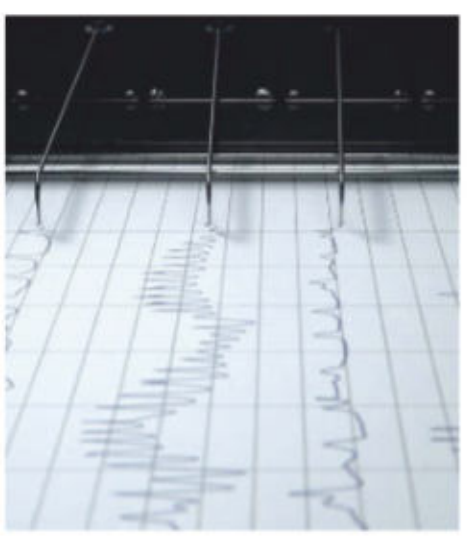
When the results were made public in 2017, the UK dropped that particular programme and replaced it with two new psychological interventions called Horizon and Kaizen. But neither has been tested in randomised trials either. A government spokesperson says the programmes haven't yet been around long enough to be tested, but evaluations are ongoing.

Other kinds of CBT scheme, such as those aimed at reducing violence, also suffer from a lack of evidence. A 2007 research summary by the Ministry of Justice reviewed 11 studies and concluded that the approach is "promising" – yet six had no effect, while the others had basic design flaws.

That isn't to say we should give up on prisoner reform. Classes or training can make it more likely people will end up in work on the outside. One large study in three US states found that those who had taken optional educational classes as inmates had a reincarceration rate of 21 per cent, compared with 31 per cent among those who hadn't. And many jails offer counselling for drug and alcohol abuse similar to that found outside jail, such as the Alcoholics Anonymous 12 steps programme, which at least has supporting evidence that it reduces alcohol use in non-offenders.

Using lie detectors to monitor ex-prisoners may not be effective



ALLAN SWART/ALAMY

While all UK prisons are supposed to offer these programmes, many inmates are unable to access them because of overcrowding or a lack of staff to escort prisoners from their cells, says Peter Clarke, the UK's chief inspector of prisons. "That leads to boredom and people using drugs," he says. "That's counterproductive in terms of rehabilitation."

40%
Rate of reoffending among former prisoners in the UK

Frances Crook of the Howard League for Penal Reform, a UK charity, says even just making prisons nicer will cut reoffending. "If you have got the best designed programme and it's working really well, delivering that to someone sharing their cell with an open toilet and cockroaches on the floor isn't going to work."

Another problem is that parole boards have no good way to assess how likely people are to reoffend. These boards tend to place most weight on psychologists' ratings of how much empathy or insight offenders have into their crimes, says Forde, who has acted as an expert witness in parole hearings.

This may be why discredited approaches like lie detector tests are increasingly called on. Such tests are already widely used in police investigations in many countries, although they aren't usually admissible in court because of their known problems.

In 2014, the UK started using compulsory polygraph testing to monitor released sex offenders. A Ministry of Justice study had shown that this technique raises the likelihood of people telling staff about incidents where they breached their parole conditions. "Polygraph testing isn't just useful for detecting lies, but for encouraging offenders to tell the truth, to reveal more information than they might otherwise," said a spokesperson.

However, there is information online about how to cheat the test, and word is likely to get round among offenders, says Chris French at Goldsmiths, University of London. "It produces too many false positives and false negatives."

Now, as well as introducing the tests for those who have been convicted of domestic violence, the government plans to use them for those who have been imprisoned for terrorist offences, such as sharing videos that promote attacks. The prospect of releasing people jailed for these offences understandably triggers alarm. But the reoffending rate among convicted terrorists in the UK is far lower, at around 3 per cent, than that of other former prisoners, which is about 40 per cent, says Marc Sageman, a forensic psychiatrist at the US Foreign Policy Research Institute, who studies Islamic radicalisation.

For domestic violence, the UK probation service aims to try to evaluate lie detectors in a three-year pilot scheme of 600 offenders, half of whom will be randomly selected to take the test. Yet reoffending rates won't be measured, which is a missed opportunity. To know whether any intervention works, you need randomly assigned test and control groups, and hard scientific data, says Sageman. "We have learned that in medicine." ■

Working hypothesis

Sorting the week's supernovae from the absolute zeros

▲ Electricity

Global carbon emissions from electricity generation fell 2 per cent in 2019 as coal use dived. Now if we could just do it a bit faster?

▲ Contagion

Downloads of the film *Contagion* – about the global spread of a deadly virus – have skyrocketed. Can't think why.

▲ SpaceX

Remember when Elon Musk shot his car into space? Wild times. The Tesla Roadster has now completed its first 557-day solar orbit.

▼ Voyager 2

In an extreme version of the Wi-Fi going down, NASA will lose the ability to command its distant Voyager 2 probe for 11 months due to radio telescope maintenance.

▼ Pedometers

A pig swallowing a fellow animal's pedometer (wait, what?) in North Yorkshire caused a huge fire after the battery reacted with porcine excrement.

TOP: RAINER DITTRICH/GETTY, BOTTOM: SERGEIKOROLKO/GETTY

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Culture columnist
Little Joe feeds off fear of GM plants, says **Simon Ings** p32

Comment

How to worry better

As the coronavirus outbreak continues, the science of dealing with uncertainty can help us make better decisions, says **Rachel McCloy**

JOSIE FORD

MANY people seem to be dealing with the recent coronavirus outbreak in one of two ways: by panicking or shrugging. There is a great degree of uncertainty around how bad the epidemic will get, which means it is easy to over or underreact and make the wrong choices. By understanding the psychology behind what is going on, it is possible to find the elusive middle ground of worry.

When we face uncertainty about the future, events can feel like they are out of our control. This often triggers negative emotions, such as fear and anger – emotions that we are motivated to try to reduce.

However, when it comes to the coronavirus crisis, the actions we take to regain a sense of control tend to be the least effective for controlling the virus. Panic buying large quantities of food and cleaning products is an example of this. Not only may this do more harm than good by creating a shortage in the supermarkets, as is happening with toilet roll, it distracts from more effective steps people could take.

Another measure that may increase our sense of perceived control more than is warranted is the wearing of face masks by healthy individuals. The masks themselves only protect from infection when fitted perfectly, and can also have unfortunate consequences. People tend to touch their faces more than usual when wearing face masks in order to adjust them, which may give the virus an alternative way into their bodies, such as through their eyes. Mask-wearing may also cause people to feel more confident that they will avoid infection. This over-optimism bias makes them more likely to engage in social contact, increasing their chances of exposure.

More appropriate things to do from a public health point of view are simple infection control actions, such as frequent and careful handwashing, general good hygiene and self-isolating if you start to show cold-like symptoms. Unfortunately, these seem to have much less of an effect on our perceived sense of control.

This is because each measure on its own feels small, and so doesn't have much of an effect on our emotions. Even though a step may not be effective, people can feel anxious about not taking it, and so they do it anyway, especially if they see those around them doing the same.

Additionally, there is the sense that, although we can do our bit by washing our hands frequently and improving general hygiene in our own homes, minimising the spread of illness is also dependent on others doing the same thing. This diffusion of social responsibility can make one person's action seem like a drop in the ocean, and again cause people to feel like they have little control.

So what to do? Boosting messages from public health organisations that provide clear and appropriate guidance is important. This will ensure these aren't drowned out by misinformation and reports that normalise unhelpful behaviours. Minimising uncertainty by making sure people hear information that is timely and relevant to their specific circumstances is also likely to help reduce short-term panic. ■

Rachel McCloy is a behavioural scientist at the University of Reading in the UK

This changes everything

The death and life of Twitter

The social media site was once a fun place, full of cat memes and a culture of sharing. Now, it could be on the brink of self-destruction, writes **Annalee Newitz**

Annalee Newitz is a science journalist and author. Their latest novel is *The Future of Another Timeline* and they are the co-host of the Hugo-nominated podcast *Our Opinions Are Correct*. You can follow them @annaleen and their website is **techsploitation.com**

Annalee's week

What I'm reading
Sarah Pinsker's incredible novel A Song For a New Day, *about how pandemics drive people into virtual reality – and then back out again.*

What I'm watching
I'm closing my eyes and listening to Paul Cooper's Fall of Civilizations *podcast.*

What I'm working on
It's covid-19 time, so I'm trying to wash my hands more often!

I WAS at the South by Southwest (SXSW) festival in Austin, Texas, in 2007, the year that Twitter turned the hallways into a marketing prank. Flat-screen monitors in the corridors broadcast a Twitter feed comprised almost entirely of people at SXSW, talking about SXSW. Frankly, my friends and I thought it was stupid.

We kept asking what this idiotic app was for. Answers were confused and various: it was for talking about things that were happening while they happened (thus creating fear of missing out, whose acronym, FOMO, hadn't yet become popular); it was for telling interactive stories in tiny chunks; it was for posting links to cat pictures. At a late-night SXSW party, one hacker told me that he had discovered the perfect way to use Twitter: he had programmed a vibrator to "read" Twitter and respond to all-caps tweets by vibrating more rapidly. We all took turns trying to make it vibrate as much as possible.

A few months later, my friends convinced me to join Twitter. They had all signed up, despite making fun of it. So I created an account to experience the latest techno-obsession of my generation, and stuck around for the "I can haz cheezburger" links. Twitter's mix of lunch commentary and personal status updates ("I hung out with @boatymcboatface and @princeharry!") felt very similar to other early social network experiments like MySpace and Tribe. I fully expected it to float into the grungy corner of the afterlife reserved for vapourware.

Now, 13 years later, I can't show you my very first tweet because I pay a few dollars a month for a service that deletes all my tweets that are more than a year old. That's right – I don't shell out cash to use Twitter, but to keep my presence extremely limited.

It isn't that I'm worried about some intrepid investigator discovering that I once said terrible things. The social world of Twitter has changed so much that I'm no longer comfortable sharing my older tweets, which feel a lot like private messages now. They were written for a few dozen people who were at most one degree of separation from my real-life friends. I wrote about where I was hanging out, my moods and what I ate for lunch. Now my tweets go out to tens of thousands of followers, most of them strangers, and are occasionally shared among anti-science types who say they would like to see me dead, and who send me regular updates about their homicidal feelings.

> **"That's right, I don't shell out cash to use Twitter, but to keep my presence on it extremely limited"**

These days, I never reveal my physical location on Twitter, unless it is to invite people to a public event I plan to attend. I would never talk about my deep personal feelings, because of the aforementioned ill-wishers. And I rarely mention what I ate for lunch, because my followers don't care and I don't want to waste their time. I tweet almost exclusively about my professional work as an author and journalist. Once in a while I make a joke that's moderately funny.

This is what it looks like when a social-media app grows up. The posts that were once a private conversation with friends are now like talking on some surreal street corner where you are surrounded by mobs of angry ghosts heckling you and threatening your family. Like a lot of people on the platform, I use apps to block trolls and bots. But that isn't a foolproof solution. You can meet more unsavoury characters in 1 hour on Twitter than you can wandering through the rough parts of a city for days.

There are a lot of reasons for this. Twitter's efforts to stop abuse and bullying on the site over the years haven't worked, and it seems its community rules still allow controversial celebrities and politicians to remain on the platform. Plus, Twitter has transformed from a nerdy cat meme haven to a highly politicised, contentious public arena. It isn't fun anymore.

Investors in Twitter are leaning into politics, too. Billionaire Paul Singer recently invested an enormous amount of money in the company, and openly attempted to oust its CEO and founder, Jack Dorsey, in a takeover. Singer is best known for two things: strong support for Trump-style Republicans, and an uncanny ability to seize control of large, flailing companies. Under Singer's guidance, the social media site could shift to the right politically.

In the aftermath of a change like that, Twitter's relevance might rapidly fade – anyone who doesn't care about right-wing politics will start looking for alternative places to post cat pictures and stories about CRISPR. The technology behind Twitter is simple, and if people begin seeking out new platforms, the tech industry will build them. It took longer than I thought it would, but Twitter seems headed for the techie afterlife. You can decide whether it will make it to the good place or the bad one. ■

This column appears monthly. Up next week: James Wong

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Editor's pick

Face recognition's faults will bring death from afar

22 February, p 13

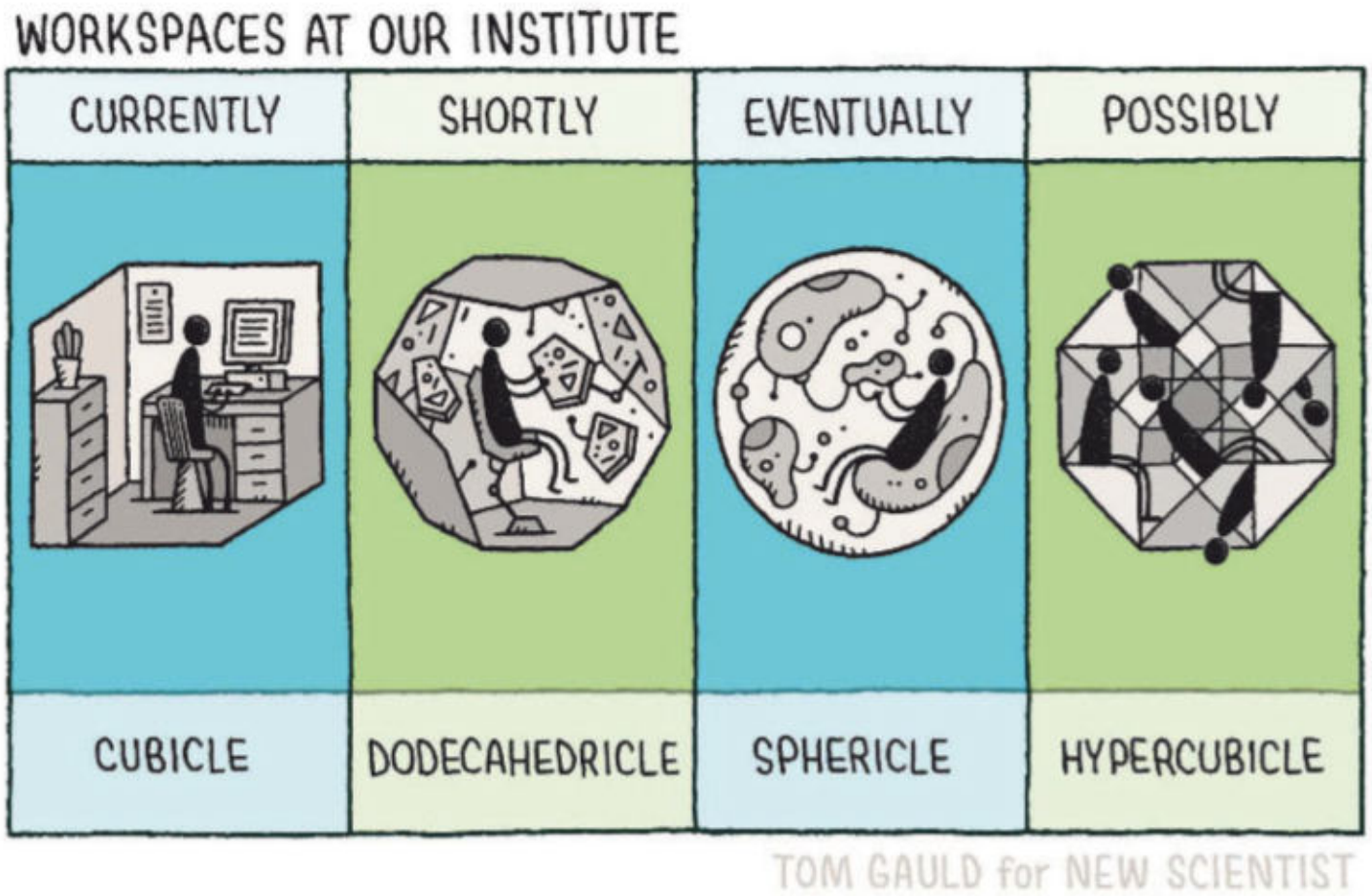
From Brian Horton, West Launceston, Tasmania, Australia

The US military is developing a face-recognition device that could be accurate from a kilometre away. The idea seems to be to use this on drones, which will presumably act when detecting a person of interest.

A separate prize challenge for such a system, from the US National Institute of Standards and Technology, allowed a false match rate of one in 1000 people. This may sound impressive, but if a drone with this technology is flying past a village of 1000 or so people, it will almost certainly pick one of them in error as a target.

From Bryn Glover, Kirkby Malzeard, North Yorkshire, UK

Long-distance, drone-mounted face-recognition systems should surely cause consternation. You have previously reported the inherent errors of this technology, particularly when dealing with faces that don't belong to white men (17 February 2018, p 5). Those tests used still photographs, presumably taken by firmly fixed static cameras that were no more than a few metres from their subjects. Amnesty International is right to be alarmed about the implications of such devices.



Smartphones can be tools against tuberculosis too

1 February, p 12

From Timothy McHugh, London, UK

I am impressed and intrigued by the skill of your picture desk in selecting eye-catching images: this is nicely demonstrated by the one printed with your article on mobile phone data and mental health. It shows a person on their phone in front of a vehicle bearing the National Health Service logo. The vehicle is the Find&Treat mobile X-ray unit of University College London Hospitals: I am part of its tuberculosis management group. Find&Treat brings diagnosis of this disease to vulnerable communities.

The picture is particularly apt as Find&Treat has pioneered the use of mobile phones for supervising antitubercular treatment. In video-observed therapy, patients are supported through a mobile phone app as they follow the demanding regimen for treatment of tuberculosis.

TB remains a global health emergency: novel approaches such as this are needed to meet this challenge. Readers may wish to learn more by joining us for World TB Day on 24 March.

More consequences of giving pigs human genes

22 February, p 18

From Karen Hinchley, Newark-on-Trent, Nottinghamshire, UK

Jessica Hamzelou addresses the ethical dilemmas around beings with a mix of human and other genes, their grade of humanity and how we treat them. These quandaries extend to the disposal of, for example, pig-human tissue. If such tissue isn't deemed "substantially human", then what disposal mechanisms should be employed?

How would you feel about such meat entering the food chain? Would that depend on the percentage of human genetic material? This is before we get to the stage of considering an adult chimera's right to live – or whether a chimera with "morally significant" characteristics, such as self-consciousness, should be offered therapy for its identity crisis. If we can't decide on a life form's value to humanity, perhaps we shouldn't put ourselves into that quandary in the first place.

We promote best practice certificates for aquaculture

Leader, 22 February

From Steven Hedlund, Global Aquaculture Alliance, Portsmouth, New Hampshire, US

You discuss the prospect of lab-made shrimp, saying it would be an improvement over shrimp farming and that aquaculture has sustainability problems.

Aquaculture aligns with the majority of the 17 United Nations' Sustainable Development Goals. It is highly resource-efficient, especially compared with terrestrial animal production.

It makes a significant socio-economic contribution in coastal and rural communities where financial opportunities tend to be limited, and produces a rich source of protein, essential fats, vitamins and minerals.

There is a worldwide effort to ensure that the proper methods are applied through third-party certification programmes like the Global Aquaculture Alliance's set of best practices.

Keeping hieroglyphics would cement privilege

8 February, p 34

From Geoffrey Harding, Sydney, Australia

Your article on the invention of the alphabet was fascinating. I suggest a further possible reason for its delayed uptake.

For scribes, intellectuals and government officials, knowledge of hieroglyphs assisted them in maintaining their positions of power and influence in society. They would rightly fear and

oppose the promotion of a simple alphabet that could make a large fraction of the population literate.

Apparently this did happen in Korea at a much later date. In around 1440, King Sejong formed a committee to develop a simple alphabet that could be quickly learned and used universally. The scribes and intellectuals who used Chinese characters tried to oppose this as a threat to their privileged positions. The king insisted, and the rest is history.

Eat like your ancestors, but not with their microbiome

22 February, p 24

From Peter Slessenger, Reading, Berkshire, UK

There are issues with the fad for eating like our ancestors, as James Wong reports. Another potential problem is with gut bacteria.

You can try to recreate a 16th-century diet, but how different were the microbiomes of people then? As with any diet, you also need to consider how much of a shock to our systems a drastic and sudden change in food may be.

Don't dismiss nuclear power out of hand

Letters, 29 February

From David Clarke, Seaford, East Sussex, UK

Paul Dorfman and others argue it is dangerous to say nuclear power is necessary to prevent climate change, in part because we can't build enough stations to achieve a carbon-neutral global energy system in time. I am not convinced we should ignore the idea that nuclear power can help meet our need to reduce carbon dioxide emissions.

The UK is projected to lose around 9 gigawatts of nuclear capacity by 2035. There are plans to build about the same amount of new capacity over this period. In addition, there is the chance – I put it no stronger than that – that the small modular reactor programme, led by Rolls Royce, is successful in providing small nuclear stations that generate up to 440 megawatts each. The modular design helps construction: it should take around 4 years to build each reactor. It is a bit early to discard the possibility of nuclear power as part of our generation mix.

Some concrete dietary advice at last, perhaps

Letters, 15 February

From Andy Ward, Middlesbrough, North Yorkshire, UK

Will Kemp says that when he was a vegan and working as a builder's labourer, his main source of calcium was sesame seed paste. He may well have ingested small quantities of cement, concrete and plaster. Could these, in fact, have been his main sources of calcium?

Why would anyone be simulating our universe?

1 February, p 42

From Hue White, Saint Paul, Minnesota, US

Donna Lu discusses the possibility that we are denizens of a computer simulation. We know that humans run simulations for distinct purposes, such as to build skills and to try to forecast phenomena. So why would "our" simulation world be run? Could we be an experiment designed to learn the nature of reality for the "next level up"?

For the record

It is in fact hard to overestimate how odd the swan-like aquatic dinosaur *Halszkaraptor escuilliei* is (15 February, p 40).

Want to get in touch?

Send letters to New Scientist, 25 Bedford Street, London WC2E 9ES or letters@newscientist.com; see terms at **newscientist.com/letters**

30 years ago, *New Scientist* took a glimpse at the latest voice-recognition technology

HEY Siri, we saw you coming. In our 17 March 1990 issue, we wrote about a computer system that could recognise continuous speech and may, we predicted, "form the basis of a personal computer controlled by voice".

At the time, this intriguing new technology had already piqued the interest of Apple, which we then described as "famous for its MacIntosh range of personal computers controlled with a 'mouse' which moves a pointer around the screen to select various icons". The company had spent several months collaborating with a research team at the University of Edinburgh, UK, to create a new system named Osprey.

The technology consisted of two standard computer boards that were plugged into the back of an IBM personal computer. "The first converts the voice signal into a digital form and then analyses the signal to pick out the key frequencies of speech," we reported. "In this simplified form the signal is passed to the second board. This holds four transputers, self-contained computers which combine processing, memory and communications on a single piece of silicon."

The transputer board then converted the important frequencies into components of speech called phonemes. There are 44 of these in the English language. Osprey had a working vocabulary of just 300 words, which its developers said could be tailored to any situation.

"The developers of the system claim it can understand any voice speaking clearly in English. It is reasonably successful with urban Scottish, they added, and they are currently working on additional software which will improve its understanding of regional accents," we wrote.

While voice control has improved drastically since Osprey was developed, many of today's popular voice assistants continue to have problems understanding certain accents or dialects that are under-represented in the data sets on which they are trained.

In 1990, Jeremy Peckham, who was then head of the speech unit at British IT firm Logica, told *New Scientist* that speech control of computers would be much slower than using Apple's mouse and icons. Thirty years later, Apple's voice assistant Siri and equivalents from the likes of Amazon and Google sit in many of our pockets and homes, ready to respond rapidly to any command. Layal Liverpool

To find more from the archives, visit newscientist.com/old-scientist

Building beauty

Photographer Alastair Philip Wiper

IMAGINE standing in a space big enough to hold more than 18,000 containers full of consumer goods.

"My strongest memory was the scale," says photographer Alastair Philip Wiper of his experience in 2014 shooting the construction of a Maersk Triple E, then the world's biggest container ship. "The shipyard was the size of a small city. Huge ship sections were moved on cranes, welded and painted by people who looked tiny."

This image of a cross-section of the ship features in his latest book, *Unintended Beauty*, and it is part of the Forms of Industry exhibition at London's Royal Institute of British Architects until 16 May.

Wiper's work explores the aesthetics of industrial and scientific sites. This shot shows the charm he found in the unfinished ship. "There are a lot of things you can say are ugly and beautiful at the same time," he writes in *Unintended Beauty*.

The ship also made waves environmentally. The Triple E label refers to its design principles: economy of scale, energy efficiency and environmental improvement. Shipping accounts for more than 90 per cent of world trade, but is also a huge polluter. In 2015, it caused 2.6 per cent of global carbon dioxide emissions.

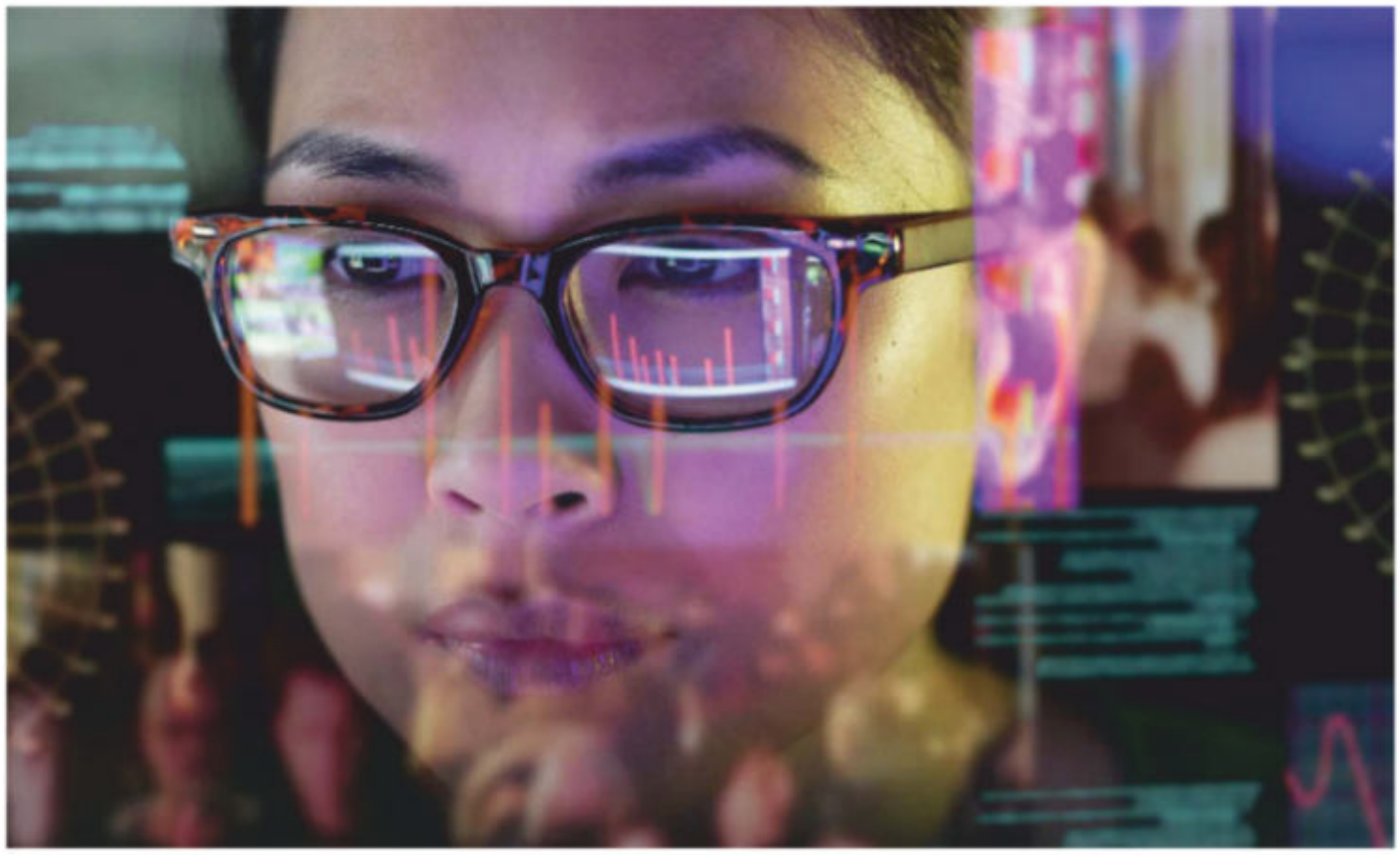
The craft has a new, slow-steaming engine that optimises speed to 30 kilometres per hour, which can lower fuel consumption and cut emissions. Its waste heat recovery system uses exhaust gas to run the onboard generator, while the redesigned hull helps the ship carry more containers.

David Stock

Protect us from dodgy stats

From genetics to immigration, our lives are ruled by statistics, so they'd better be good. **Timothy Revell** tries a podcast that sifts the factual from the flaky

Podcast
Risky Talk
Libsyn



LAURENCE DUTTON/GETTY IMAGES

Deciphering statistical data is rarely a straightforward task

"I'VE got a lower than average risk of developing coronary heart disease and Alzheimer's and a higher risk of getting psoriasis and coeliac disease. And I have got absolutely no idea what to do with this information," says David Spiegelhalter, in *Risky Talk*, a monthly podcast about statistics that started this month.

For Spiegelhalter, an academic who has spent years trying to improve the public understanding and image of statistics, this kind of information illustrates why he has had his work cut out – and why genetic risk is a good topic for the first episode.

"We are all bombarded by misleading anecdotes and biased information, whether it's people trying to sell us stuff or persuade us to vote for them. But to make vital, everyday decisions, from the personal to the political, we need a clear view of the best evidence about risks and benefits," he says.

A few years ago, Spiegelhalter sent saliva to a consumer DNA testing company, which resulted in those perplexing findings. We can all pay for such tests, but they are also being rolled out on a large scale in medical settings. The US National Institutes of Health plans to sequence a million genomes and the National Health Service in the UK has a 10-year plan to use genetic sequencing more often.

The biggest problem isn't the stats per se, but knowing what to do with them. So far, tests flag a few genetic conditions where you can reduce your risk by adjusting your lifestyle or through medical intervention. But in most cases, there is little you can do, in which case stats aren't just unhelpful, they can also induce anxiety.

Saskia Sanderson, a behavioural scientist at University College London and a panellist in this episode, says she has found an answer to this. When people are properly informed about the possible outcomes of testing, they tend to be good at opting out of taking a test if they think they won't be able to handle the news.

> **"Migration is a political hot potato, so whatever your political leanings, shouldn't getting better figures be a no-brainer?"**

However, few doctors are trained to explain the implications of genetic testing, and an NHS source told *New Scientist* last year that there were only 200 genetic counsellors in England.

In episode 2, *Risky Talk* moves on to other hot topics: crime, immigration and opinion polls. This time the problem is a shock. It isn't that there is lots of good data and no one to interpret it, more that some key stats are, well, flaky.

Take immigration. Spiegelhalter finds a statistic showing that 13,000 fewer people migrated to the UK, but when he downloads a relevant table from the UK's Office for National Statistics (ONS), he finds that the margin of error is plus or minus 73,000. "This seems rather large," he says.

It gets worse. The way these numbers are generated is even flakier. Ed Humpherson at numbers watchdog the UK Statistics Authority says that the immigration estimate primarily comes from an "intention survey". This is a questionnaire the ONS uses for people entering and leaving the UK, asking about their trip, whether they intend to stay long and so on. No one has to reply.

Millions of people pass through the country during the year, but the ONS bases its number on just 5000 responses. Its final estimate is a result of combining this tiny data set with other figures, such as the number of visas awarded.

The UK Statistics Authority awards a quality mark for statistics, and it has recently removed one of its marks from the immigration figures. Migration is a political hot potato, so whatever your political leanings, shouldn't getting better figures be a no-brainer?

If only. "Statistics aren't just numbers, they are numbers with a social life," Humpherson argues. They are sought by people, governments and corporations with agendas who want to appear to use cold facts to justify their arguments. Small wonder people feel they can't trust statistics, or the experts who cite them.

In that light, Spiegelhalter's attempts to sift the good from the bad and generally improve the dialogue can only be welcome. ■

TikTok's global surge

More than 3 million people a day are downloading a video-sharing app. **Chris Stokel-Walker** explores why

Video app

TikTok

IT HAS rejuvenated the music industry and given birth to a new generation of celebrities, including the likes of Charli d'Amelio, a 15-year-old social media personality and dancer. More than 3 million people a day downloaded video app TikTok in January, according to tracking company Sensor Tower. Its rise to become one of the big beasts of social media has been remarkable, so how did TikTok do it?

The app, which people use to share short videos, often accompanied by clips of music, is a modern media phenomenon. The firm sponsored the BRIT awards for music in February, with chart-topping singer Lewis Capaldi as its poster boy. Actors including Will Smith, and music stars like Justin Bieber, also use it.

TikTok's parent company ByteDance, based in Beijing, China, bought an advert to promote the app at American Football's flagship Super Bowl game, and the Jama Masjid, one of the largest mosques in India, has posted signs outside its door saying "TikTok is strictly prohibited" after a video of two women doing a headstand inside its premises went viral.

Some people say its success is down to its brief content. "TikTok separated themselves brilliantly from the rest, focused on the things they're good at and reinvented short-form content when the rest of the world is turning to long form with companies like Netflix," says Harry Hugo, co-founder of The Goat Agency, a marketing firm. Unlike everything else, the platform "allows you to be effortlessly famous in a very short amount of time", says Hugo. It is also buoyed by the fact that the videos are no more than 60 seconds long, and usually more like 10 or 15, and presented in an endless scroll.

"People don't have a very long attention span nowadays, so it's appropriate the videos are short," says Anna Bogomolova, who posts content including her dancing to popular songs and performing comedy skits. Bogomolova has 2.3 million followers on the app.

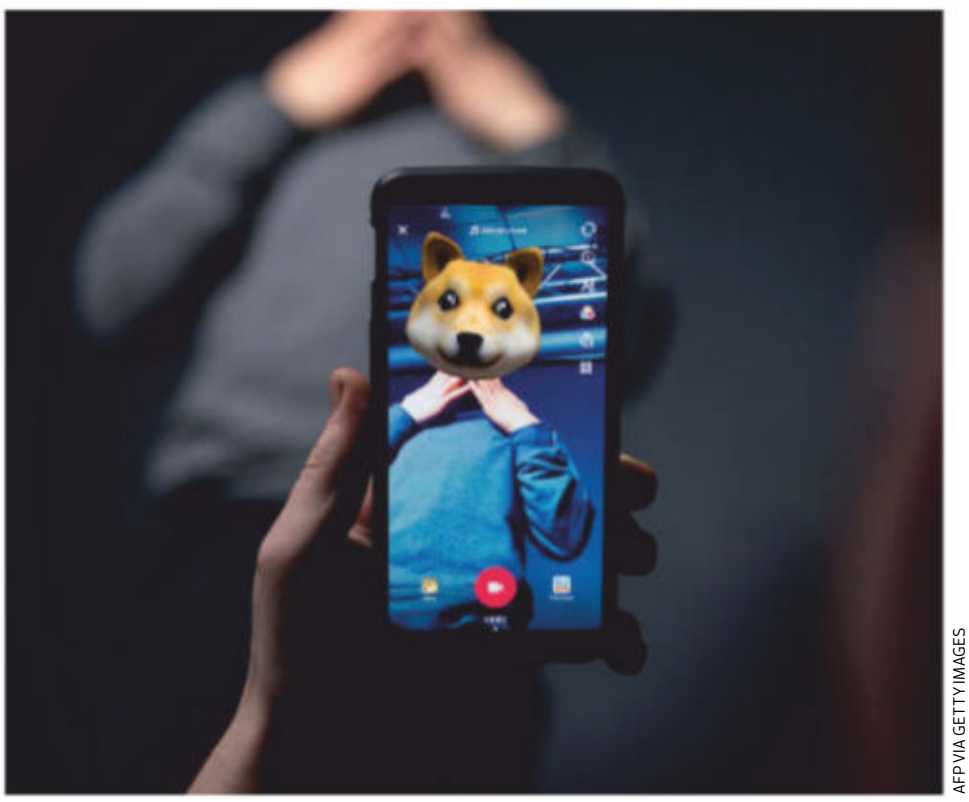
She initially posted on Musical.ly, an app that allowed users to lip-sync to their favourite songs, before it merged into TikTok in August 2018. The change was significant, she says: "Now because people are doing dances, comedy, acting or art, everyone else is encouraged to try different things as well."

This gives it great appeal, says Rich Waterworth, general manager of TikTok in the UK. "What makes TikTok so popular is that the experience is different for everyone: there's no one thing that defines it," he says. "So much of what trends on TikTok has become the origin of cultural conversation in the mainstream. Our success lies in capturing moments in the lives of ordinary people, like the farmer at @caenhillcc in rural England, teaching people the ins and outs of agriculture, or self-trained comedian @ameliagething, whose popularity on TikTok landed her a professional career in broadcasting."

The app is also adding options to make money through a creator marketplace, which connects brands to talent, and in-app advertising.

Since the merger with Musical.ly, TikTok's popularity has exploded. ByteDance doesn't release figures, but a leaked media kit for potential advertisers in December 2018 showed that the average user opened the app 121 times a week, and spent nearly 27 minutes a day in it. TikTok's meteoric rise shows few signs of slowing. ▮

Chris Stokel-Walker is a technology writer based in Newcastle, UK



TikTok's brief videos may work well for our short-attention spans

AFP VIA GETTY IMAGES

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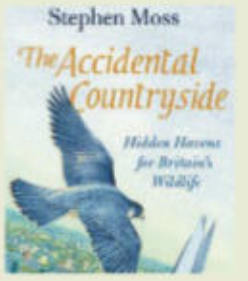

Read

The Accidental Countryside (Faber) by naturalist Stephen Moss explores some very unlikely oases for hard-pressed wildlife in the UK, from ultra-modern skyscrapers to lowly railway cuttings.

Watch

Altered Carbon: Resleeved sees *Cowboy Bebop* writer Dai Sato bringing his unique eye and cultural obsessions to the *Altered Carbon* universe, in an anime spin-off of the live-action sci-fi hit. On Netflix from 19 March.

TOP: BBC

The film column

What if plants have feelings too? A film about a flower that makes people happy seems to play on fears around genetic modification. When the plants attempt to propagate at all costs, few can spot what they are up to, says **Simon Ings**

Simon Ings is a novelist and science writer. Follow him on Instagram @simon_ings

MONGREL MEDIA

Alice (Emily Beecham) loves the plant creations she calls her Little Joes

Film

Little Joe

Directed by Jessica Hausner

Simon also recommends...

TV/Film

The Quatermass Experiment (1953)

Written by Nigel Kneale

The first science fiction written for an adult British TV audience. Astronaut Victor Carroon mutates into a plant-like organism. Two episodes survive. Watch on DVD, along with a serviceable 1955 film version.

Film

Upstream Color (2013)

Directed by Shane Carruth

Earth is visited by aliens whose mind-blowing animal/vegetable/mineral life cycle confirms Shane Carruth as someone who is incapable of telling a simple story.

THEY are red, they have stalks that look like eels, and no leaves. But Karl, the boss of the laboratory – played by the unsettling David Wilmot – has his eye on them for the forthcoming flower fair. He tells visiting investors that these genetically engineered creations are "the first mood-lifting, antidepressant, happy plant".

Ben Whishaw's character, Chris, smirks: "You'll love this plant like your own child."

Chris is in love with Alice, played by Emily Beecham, who is in love with her creations, her "Little Joes", even to the point of neglecting her own son, Joe.

Owning and caring for a flower that, treated properly, will emit pollen that can induce happiness, would surely be a good thing for these characters. But the plant has been bred to be sterile, and it is determined to propagate itself by any means necessary.

Little Joe is an exercise in brooding paranoia, and it feeds off some of the more colourful fears around the genetic modification of plants.

Kerry Fox plays Bella, whose disappointments and lack of kids seem to put her in the frame of mind to realise what these innocent-looking blooms are up to. "The ability to reproduce is what gives every living thing meaning!" she exclaims. Her colleagues might just be sceptical about this because she is an unhappy presence in the lab, or they may already have fallen under the sway of Little Joe's psychoactive pollen.

> **"Popular fears about GM that scuppered the industry's experiments in the 1990s are nearly as old as genetics itself"**

Popular fears around GM – the sort that dominated newspapers and scuppered the industry's experimental programmes in the mid-1990s – are nearly as old as the science of genetics itself.

At about the turn of the 20th century, agricultural scientists in the US combined inbred lines of maize and found that crop yields were radically increased. Farmers who bought the specially bred seed found that their yields tailed off in subsequent years, so it made sense to buy fresh seed yearly because the profits from bigger crops more than covered the cost of new seeds.

In the 2000s, Monsanto, a multinational agribusiness, added "terminator" genes to the seed it was developing to prevent farmers resowing the product of the previous year's crop. This didn't matter to most farmers, but the world's poorest, who still rely on replanting last year's seed, were vociferous in their complaints, and a global scandal loomed.

Monsanto chose not, in the end, to commercialise its terminator technologies, but found it had already created a monster: an urban myth of thwarted plant fecundity that provides Jessica Hausner's *Little Joe* with its science fictional plot.

What does Little Joe's pollen do to people? Is it a vegetal telepath, controlling the behaviour of its subjects? Or does it simply make the people who enjoy its scent happier, more sure of themselves, more capable of making healthy life choices? Would that be so terrible? As Karl says, "Who can prove the genuineness of feelings? Moreover, who cares?"

Well, we do, or we should. If, like Karl, we come to believe that the "soul" is nothing more than behaviour, then people could become zombies tomorrow and no one would notice.

Little Joe's GM paranoia may set some *New Scientist* readers' teeth on edge, but this isn't ultimately, what the movie is about. It is after bigger game: the nature of human freedom. ■

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Gotta run?

Is it better for your health to run or walk? Sports engineer **Steve Haake** sets off in search of an answer

PBNJ PRODUCTIONS/GETTY IMAGES

I hated physical education at school. Cross-country was the worst: cold, boring and lung-burning. "Run, don't walk!" the teacher would shout as we jogged reluctantly through the mud, only to walk as soon as we were out of sight.

Over the following four decades, my PE teacher's angry barks have been echoed in the constant media reports telling me that I should run, whether informing me that jogging could increase my lifespan by years or that training for a marathon would make my heart younger.

The benefits of exercise are huge. If it were a drug, it would be a miracle cure. It keeps our hearts strong and blood vessels supple, lessens chronic inflammation and reduces the harmful effects of stress.

But do we need to run to get the benefits or can we get a sufficient dose just from walking in the limited time we have for exercise? And what about those who warn about the toll on joints from pounding the pavement? It is common knowledge that running causes arthritis and ruins the knees and hips – but does the evidence back this up? I wanted to find out if my PE teacher's mantra was right.

The idea that running is the best exercise for us – indeed, that it is part of what makes us human – has many champions. Among them is Daniel Lieberman at Harvard University, who maintains that we evolved to run long distances. He thinks that our now largely untapped talent for persistence hunting – chasing animals over long distances – in hot conditions gives us an edge over other animals and shaped our evolutionary history.

And we aren't just good at running because we are good at walking – in fact, technically they are quite different (see "Mechanics of locomotion", page 36). A range of adaptations such as sweat glands and hairless skin to aid cooling, the right balance of muscle types and a special ligament to keep our head stable when running all mean that, over long distances, we can outrun almost any other animal. "Thanks to our evolutionary history, all of us have the anatomy and physiology needed to walk and run – assuming we are not disabled," says Lieberman. "In today's world, we have medicalised, commodified and commercialised exercise, but physical activity, at its heart, is something we evolved to do."

It is somewhat ironic then that many of us today are almost entirely sedentary. The current US and UK government guidelines for physical activity recommend that adults do at least 2.5 hours of moderate exercise or 75 minutes of vigorous exercise every week. In the US, only half the population meet these guidelines, and the situation is only slightly better in the UK. But what counts as moderate and vigorous exercise?

Back in the late 1980s, Bill Haskell at Stanford University in California asked the same question and came up with a benchmark to compare exercise against – sitting quietly. When seated, we expend about 1 kilocalorie per hour for each kilogram of body mass. Haskell and his colleagues called this a metabolic equivalent, or 1 MET. For an 80-kilogram person, this resting metabolic rate represents around 1920 kcals per day.

Taking it easy

All physical activities can be expressed in METs, and there is now a Compendium of Physical Activities that contains an eclectic mix of them described using this system. This elegant solution to the definition of exercise has three categories: light exercise up to 3 METs, moderate exercise between 3 and 6 METs and vigorous exercise for anything over 6 METs (see "Measuring the burn", page 37).

Strolling, at about 2 METs, is light exercise, while walking briskly is in the middle of moderate at 5 METs. The transition to running at around 7 kilometres per hour is where exercise enters the vigorous category. A really brisk walk and a slow run are roughly the same, in terms of effort and calories burned. But is this true of their health benefits too?

At first glance, it might seem that running has the upper hand here. A study from January, for example, was enough to make anyone sign up for a marathon. This looked at 138 first-time marathon runners and found that training for and completing the 26-mile race, even at a slow pace, is equivalent to a 4-year reduction in age of the cardiovascular system, or even more for those who are older and less fit. ›

Mechanics of locomotion

When people walk, at least one foot is always touching the ground. It is an efficient technique in which, mechanically, the body acts like an inverted pendulum during each foot's contact. Each of us has an optimum stride frequency related to the length of our legs – the longer they are, the lower the frequency.

Running is less efficient and the motion is more like the compression of a spring than a pendulum's swing. The movement is characterised by a flight phase when both feet are airborne, followed by one foot making contact with the ground for a mere quarter of a second or so. During this impact, the body experiences forces that are more than double those encountered when standing.

Is exercise worth it?

Runners and other active people tend to live longer. But if these bonus years are equivalent to all the time spent working up a sweat throughout life, then is it all a waste of time? It is a pertinent question for those who find exercise a penance.

Duck-chul Lee of Iowa State University and his colleagues dug into the data to find out. They calculate that between the ages of 44 and 80, someone who runs 2 hours per week will spend a total of 0.43 years running. This would still provide an average "bonus" of 2.8 additional years of life on top of the time spent running. In other words, 1 hour of running typically adds an extra 7 hours to lifespan. "It is controversial whether progressively more running provides further mortality benefits, but running certainly provides cost-effective longevity benefits," they concluded.

Running also gets a glowing bill of health in several large-scale studies that follow people for many years: they show that this exercise has a dose-related effect. More running is better, though with diminishing returns, but the good news for couch potatoes is that the largest gains come by going from nothing to something. "The biggest health benefits are observed with just a little running per week, less than 60 minutes, an amount that would fit in most people's schedules," says Angelique Brellenthin, an exercise researcher at Iowa State University.

Further benefits are clear from long-term US studies. In the National Walkers' and National Runners' health studies, Paul Williams and Paul Thompson of the Lawrence Berkeley National Laboratory measured the health of about 16,000 walkers and 33,000 runners over six years. Compared with walkers, runners had a 38 per cent lower risk of high blood pressure and a 71 per cent lower risk of type 2 diabetes.

When the researchers controlled for energy expenditure and weight difference between the groups, however, the benefits from walking and running were comparable. Williams later analysed data for breast and brain cancer, and the reductions in risk of death from running or walking were, again, similar if energy expenditure was the same.

Even a small amount of exercise brings significant health gains. This was the case in a massive study from 2011 that followed more than 400,000 people in Taiwan over an average of eight years, noting their exercise habits and the number of deaths from different causes. This showed that just 15 minutes a day of moderate exercise such as fast walking was enough to reduce risk of death by 10 per cent compared with sedentary participants. This effect could also be gained by around 5 minutes of vigorous exercise such as running, giving a time-versus-benefit ratio between running and walking of three to one (see "Survival of the fittest", right).

So far, so clear. If you have time on your hands, the gains of walking are comparable to those of a jog so long as you are moving at a moderate pace. But for the time poor, running is the best way to get a dose of exercise. "The fact that running confers similar benefits as walking but in half the time is one major reason that running is attractive for health,"

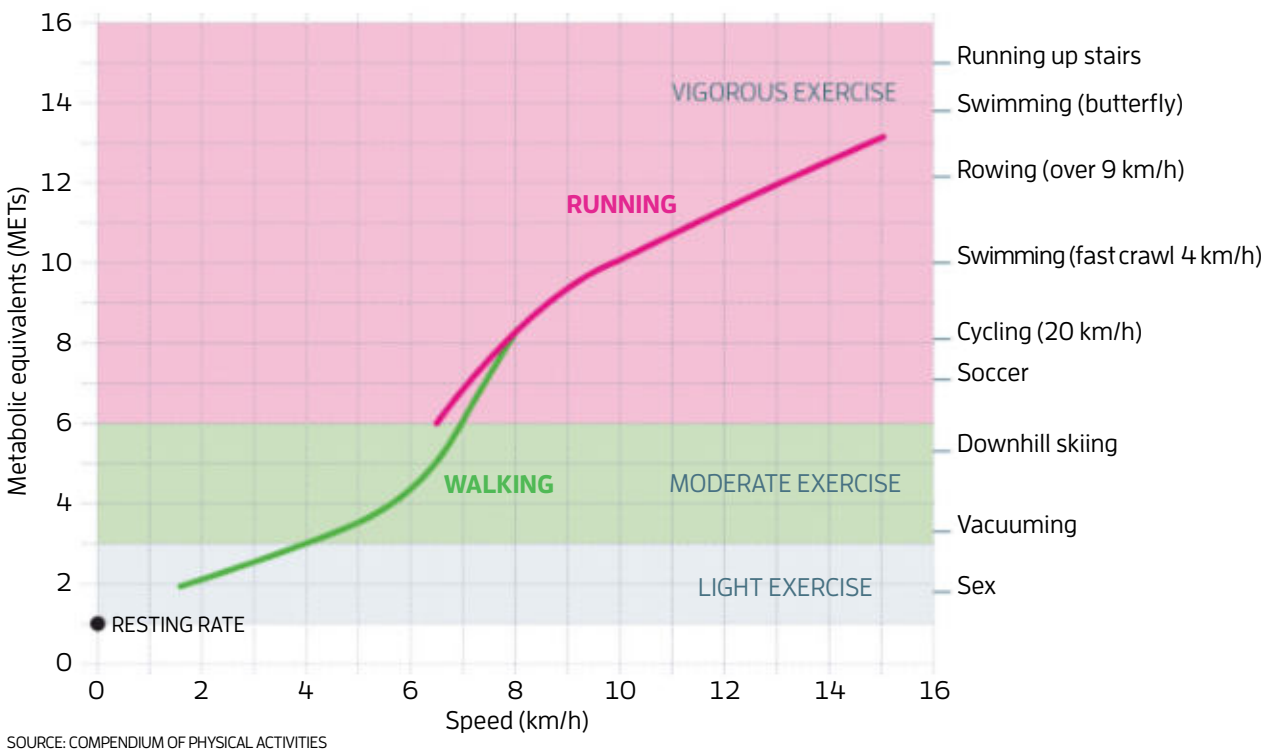
"The largest gains come by going from nothing to something"

ZIVICA KERKEZ/ALAMY

Even walking the dog confers a boost to health

Measuring the burn

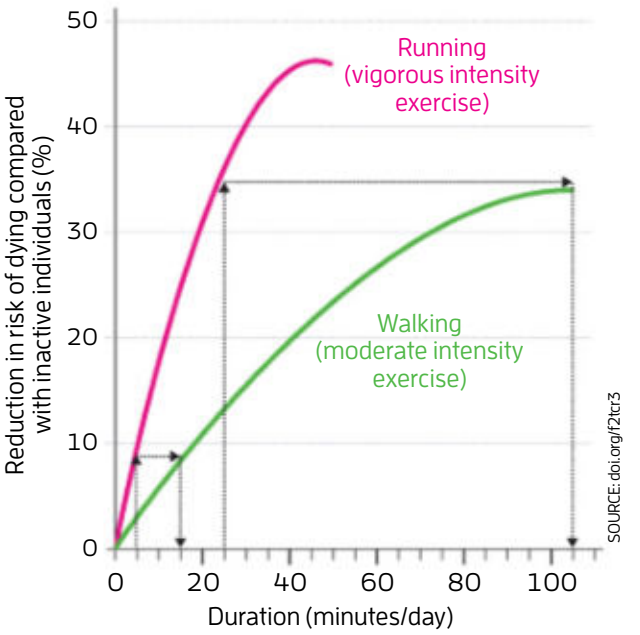
The energy expended during exercise can be measured in metabolic equivalents (METs), where 1 MET is the metabolic rate at rest. Walking counts as vigorous exercise, if you go fast enough



SOURCE: COMPENDIUM OF PHYSICAL ACTIVITIES

Survival of the fittest

Even a small amount of exercise boosts health, but this effect tapers off with increasing time spent exercising



A 5-minute run generates the same benefits as a 15-minute walk, and a 25-minute run is equivalent to a 105-minute walk

says Brellenthin. "There may be additional benefits of running, particularly for cardiovascular health, related to the higher intensity of running. However, intensity is relative to individual fitness levels, and a brisk walk will provide numerous health benefits for people like beginners and older adults."

This is great news for joggers and hikers, but not if our body gets worn out or injured in the process. Could this risk outweigh the benefits?

There is no doubt that running is a high-impact activity. When the foot hits the ground, a force equivalent to two or three times your body weight pushes up through the body. Bones, joints, muscles and ligaments must absorb this force. The question is whether this wears your joints out, as many of us believe.

As I get older, this is something I worry about. I'm not alone. "Most people understand that exercise is good for you, that it is good for the cardiovascular system, but at what expense, if you've worn your knees out in the process?" says Alister Hart, a surgeon at the Royal National Orthopaedic Hospital in London. This question was on his mind back in 2012, when he was hobbling around after completing his first marathon, so he decided to study the impact of marathon running on knees.

Together with his colleague Laura Maria Horga and others, he recruited 82 runners taking part in the London marathon, all of whom were over 40 and had never run this distance before. Using MRI, the runners' knees were scanned in detail six months before the race and again a few weeks after. The scans revealed that the knee's main weight-bearing compartments – the parts most likely to develop arthritis in the long term – had become stronger as a result of the marathon training. "It was a very big surprise," says Hart.

The kneecap part of the joint, however, did show damage, but follow-up scans revealed that this had reversed six months later, when the participants had reverted to less intense running regimes. Hart's take-home message is "distance running can have long-term benefits for your knees". The team also did a study on hips, which found that 560 kilometres of a marathon training programme, ending in the race, didn't cause pre-arthritic changes in the hip joint. "Our findings suggest that the high impact forces during marathon running were well tolerated by the hip joint," says Horga.

Wear and tear

Another treasure trove of data on wear and tear comes from the National Walkers' and National Runners' health studies. As part of this, Williams looked at osteoarthritis, which is caused by the breakdown of bones or cartilage in joints. He found that doing more running or walking actually reduced the risk of osteoarthritis and the need for hip replacements. It didn't seem to matter if the participants walked briskly or ran slowly.

The idea that running wears the body out is a myth, says Lieberman. "In fact, quite the reverse. Running helps activate all kinds of repair and maintenance mechanisms," he says.

But it is possible to overdo it. A 2017 meta-analysis including more than 125,000 people found that 3.5 per cent of recreational runners had osteoarthritis in the hip or knee compared with 10 per cent of sedentary non-runners. Yet 13 per cent of elite runners who had taken part in international competitions had such osteoarthritis. For recreational runners at least, it seems there is a sweet spot at which running protects against osteoarthritis.

That is good news for most joggers, but what about the risk of strains and sprains? "Running, like everything, however, has trade-offs including greater risk of injury," says Lieberman.

When it comes to injuries such as sprains, walking beats running hands down. A study of the exercise habits of more than 14,000 Spanish graduates, for instance, found walking resulted in 40 per cent fewer injuries than running for equal energy expended. The injury rate of running was less than that of football, sailing and martial arts, and similar to that of skiing and tennis.

The risk of injuries from running depends on factors such as how long you have been doing it, as well as your age and sex. A 2015 meta-analysis of 13 studies of running-related injuries found that novice runners were most likely to get ›

AVOIDING THE DOWNSIDES

Rebecca Robinson is a doctor specialising in sports medicine at the Centre for Health and Human Performance, London, and an elite marathon runner. Here are her tips for avoiding running's drawbacks.

SLOW BUILD-UP

The forces that bones experience during running are much higher than for walking. Following a training programme that gets progressively more intense can promote bone growth, and strengthen the muscles that can absorb more force, as well as associated ligaments and tendons.

MIX IT UP

Bone strengthening in adults happens only in the direction of the load placed on it, so combining running with multidirectional strengthening exercises can maximise the whole-body benefits. A balance of running and "resistance training" such as gym workouts, yoga or Pilates can build up muscle and bone. For experienced runners, trail and mountain running mixes up the direction of the loads placed on the body.

YOU'RE NEVER TOO OLD

Running plus resistance training can maintain the muscles that support joints. This is true even as we age. Muscle mass peaks in our 20s and 30s, then naturally declines. However, strength, endurance and balance training even into our 70s, 80s and 90s counteracts this. This is important for keeping older runners on the move, and protects against falls and frailty.

REST

Our bones need a recovery period to adapt to the loads they experience. Too much load can outstrip the ability of bone to lay down new cells, which can result in a debilitating stress fracture. So remember that rest is training too.

DON'T SWEAT IT

Physical activity can be very beneficial for mental health, including depression and anxiety. However, overtraining can lower mood, as can focusing too intently on the results of training. Finding the right balance between enjoyment and striving is key.

COURTESY OF PARKRUN

On a parkrun, it is still 5 kilometres whether you walk, jog or go flat out

injured, sustaining around 18 injuries per 1000 hours of exercise. At an average pace of nearly 10 kilometres per hour, this is equivalent to about one injury every 540 kilometres, more than double the rate of more experienced runners. Unsurprisingly, one of the most important risks is the existence of a previous injury. "I think learning how to run sensibly and properly can help mitigate those risks," says Lieberman (see "Avoiding the downsides", left).

Weighty issue

But what about those terrifying stories of people who cross a marathon finish line only to drop dead? Some studies show that the health benefits of running tail off, or even reverse, when running more than 4.5 hours a week. Crucially though, the risks from any amount of running are always lower than from doing no running at all and, on average, runners live three years longer than non-runners. "People who engage in high amounts of running still have health benefits compared to non-runners, but there is probably a point of diminishing returns," says Brellenthin.

There is good news for runners on the obesity front too: runners tend to weigh less than walkers. This could be because thinner people are more likely to run, but a study by Williams suggests running helps shed excess weight. It showed that reductions in body mass index were significantly greater from running compared with walking when these activities were matched for energy expenditure. This could be due to a greater increase in metabolic rate after more intense exercise.

So where does this leave us in the walk/run debate? Was my PE teacher right that running is a better way to exercise than walking?

The research clearly shows that both are good for you. They improve cardiorespiratory fitness and reduce blood pressure, body mass index and the risk of a host of diseases. For the biggest bang for your buck though, running has the edge, mostly because you can get more exercise done in a given time. But if you expend the same amount of energy when you walk, the benefits are quite similar. In other words, if you prefer walking, go for a long one, ideally with a few hills. And remember that any amount of exercise is better than none.

This philosophy might explain the success of an exercise phenomenon that is sweeping the globe: parkrun. These free, timed 5-kilometre community events take place every Saturday morning in more than 20 countries. They are wildly popular, with 6 million people signed up. Key to parkrun's success is that you can cover the distance however you want: by running, walking, pushing a child in a buggy or loping with a dog. Participants rate the impact on their fitness and happiness so highly (I know, because I carried out the research to find out) that family doctors in the UK now prescribe parkrun to their patients.

My PE teacher would be astonished to discover that I enjoy running now and rarely miss a parkrun. If I did meet him, though, I would gently point out that we don't necessarily have to run. After all, the most important exercise is the one you actually do. ■

Steve Haake is at Sheffield Hallam University, UK, and author of *Advantage Play: Technologies that changed sporting history*

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Number crunch

Our appetite for data is becoming unsustainable. We urgently need to rethink computing, reports **Edd Gent**

THE modern world is drowning in data. In 1984, the global traffic of the fledgling internet amounted to 15 gigabytes per month. By 2014, that had become the average traffic per user. In 2019, each of us burned through that much data in just over a week. The floodgates show no signs of closing, either. As billions of new users come online, and ever more devices become web-connected, the amount of data in the world is forecast to rise to 175 zettabytes (10^{21} bytes) by 2025 – more than three times humanity's output to date.

Processing these oceans of data requires enormous infrastructure, extending beyond smartphones and personal computers to millions of energy-hungry data centres around the globe. That combined hum already uses 6 per cent of the world's electricity, an energy bill predicted to double by 2030, raising concerns about the sustainability of our digital habits.

For decades, technological improvements kept the rising waters at bay, allowing hardware to get smaller, faster and more energy efficient. But the silicon chips we rely on are starting to hit physical limits, threatening to leave us with an energy bill we can ill afford to pay.

A plethora of alternative technologies are vying to continue the upward march in processing power, but most are still languishing on the lab bench. That is why a growing number of researchers are calling for something more transformative: a complete rethink of the thermodynamics underpinning computing. If the idea gains traction, it could revolutionise how computers are designed, allow processors to grow more powerful without huge extra energy demands, and sate our growing appetite for data.

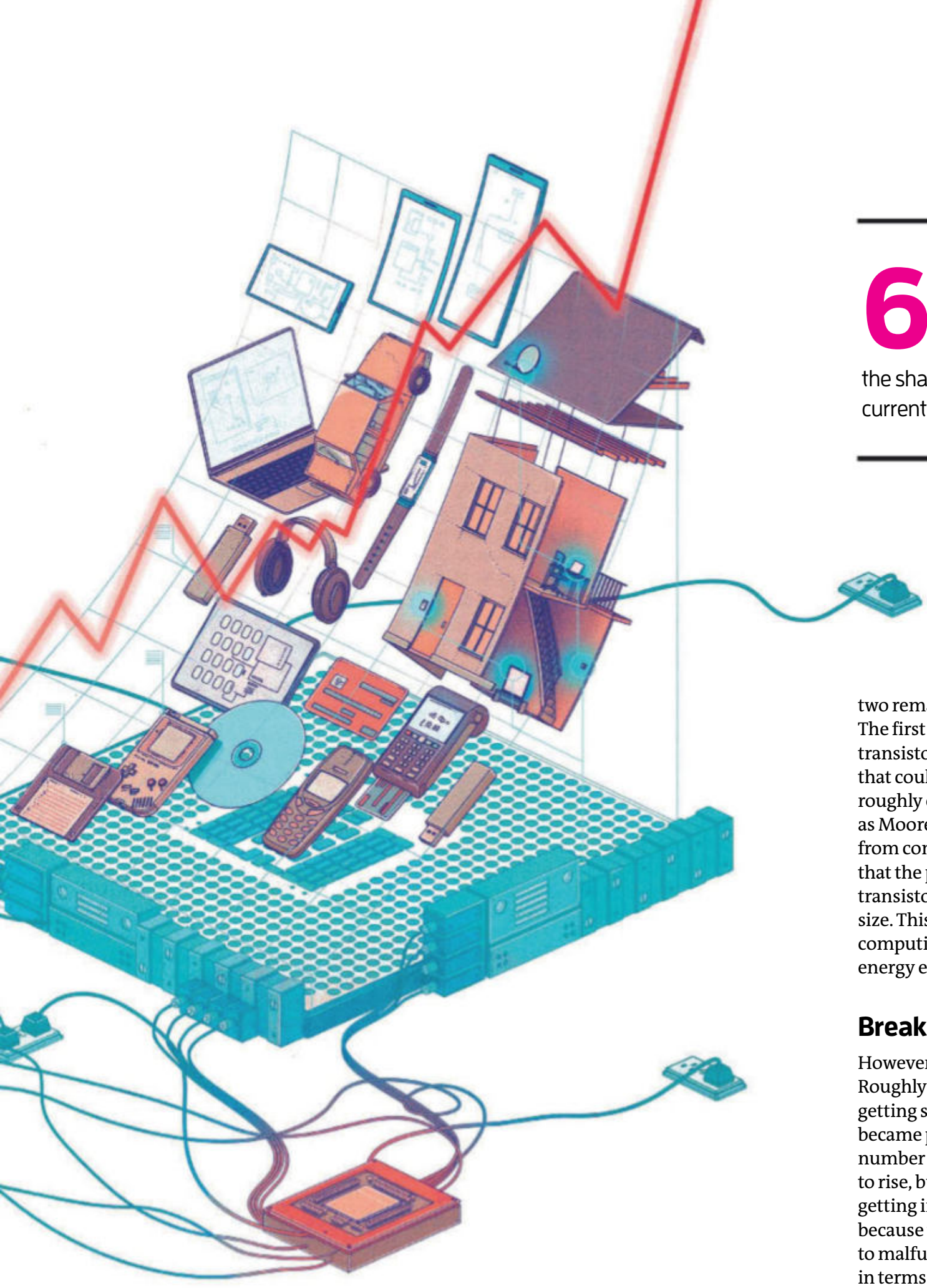
DOUG JOHNMILLER

Anyone who has ever sat with a laptop on their knees knows computers give off heat. A lot of heat. That is an unavoidable consequence of how they work, and to understand why, we have to think about what computers do. Broadly speaking, they are machines capable of storing and manipulating information. Computers do that in the form of bits: fundamental units of digital information that can adopt one of two states, either a 0 or a 1. These are represented in computers by tiny electronic switches called transistors that flick on and off when a voltage is applied. This process generates electrical resistance in computer chips, which manifests as heat. Given that modern computer chips feature billions of transistors working together, this can raise the temperature considerably.

In 1961, IBM physicist Rolf Landauer set out to calculate the theoretical efficiency of a perfect computer – one that wasted none of its energy in combating resistance. He knew that such a device would still consume some energy. That is because, like all machines, computers are constantly fighting one of the most powerful forces in the universe: the second law of thermodynamics. This states that the disorder of any closed system – a measure known as entropy – will always increase. It is why eggs don't unscramble and marbles are easier to spill than clean up. As anyone who has tried to tidy up after their children knows, restoring order costs energy.

Landauer reasoned that corralling information is a rebellion against disorder and so represents a decrease in entropy that can only be bought with energy. He worked out that even the simplest computation possible – erasing a single bit – must incur a tiny thermodynamic debt, no smaller than 2.8×10^{-21} joules. Operating at this efficiency, Summit, the world's most mighty supercomputer, could be powered by a few milliwatts. In reality, it uses 13 megawatts, the approximate peak output of two offshore wind turbines.

Even this is astonishingly efficient compared with early computers. The Cray 1 supercomputer, unveiled in 1975, used roughly 1 per cent of that power, but had less than a billionth of the computational muscle. The shift to where we are today was enabled by



6 per cent

the share of the world's electricity currently devoted to computing

175 zettabytes

the total amount of data forecast to exist by 2025

two remarkable trends working in tandem. The first was industry's ability to miniaturise transistors and double the number of them that could be squeezed on a computer chip roughly every two years, a trend referred to as Moore's law. The second was an observation from computer scientist Robert H. Dennard that the power consumption of individual transistors fell in proportion to their reduced size. This meant you could double a chip's computing power at the same time as its energy efficiency.

Breaking Moore's law

However, these advances couldn't last forever. Roughly 15 years ago, silicon transistors started getting so small that further efficiency gains became physically impossible. Today, the number of transistors per chip continues to rise, but packing them closer together is getting increasingly complicated. This is because the extra heat given off causes chips to malfunction. "We really are hitting a wall in terms of designing these at smaller and smaller dimensions," says Iris Bahar at Brown University in Rhode Island. "We are getting close to the limit of how efficient they can be." For the first time in 50 years, Moore's law is beginning to falter (see "Power slump", page 43).

At the same time, demand for ever smaller, ever more powerful computers is booming. Upgrading mobile data networks from 4G to 5G technology, which will make download speeds up to 100 times faster, is expected to see average monthly data use in North America balloon from 8.6 gigabytes per person in 2019 to 50 gigabytes in 2024. There has also been an explosion in web-connected devices, ›

from smart fridges and fitness watches to smart meters and factory monitoring equipment, all pumping out data. This so-called internet of things spanned 9.5 billion devices in 2019 and is due to reach 28 billion by 2025.

In 2017, Huawei researcher Anders Andrae predicted that the tsunami of data crunching resulting from all this would consume a fifth of the world's electricity by 2025. That figure understandably made headlines. His latest predictions are less apocalyptic, but still suggest that more than 10 per cent of the world's electricity could be devoted to information processing by 2030. In terms of raw power, that would be more than is currently used by the whole of the EU. Such growth is likely to represent a significant future source of carbon emissions, and keeping data centres from overheating will require unsustainably vast quantities of cooling water.

Not everyone believes such a dramatic energy crunch is coming. "Andrae's models are pretty simplistic frankly," says Eric Masanet at Northwestern University in Illinois. He says they extrapolate from older studies of computing's energy use, an approach that has historically led to overestimates. In a recent study, Masanet and his colleagues found that the energy use of data centres only increased by 6 per cent between 2010 and 2018 despite a 550 per cent increase in their workload.

That was thanks to improvements in hardware as well as energy management, but Masanet thinks further efficiency gains will be required. "We need to start paying more attention to the potential for rapid growth in energy use and we need to start doing what we can to avert that," he says.

"We might be able to design computers that are three or four orders of magnitude more energy-efficient"

Turning down the heat

That's precisely the motivation behind a host of alternative technologies hoping to exploit new materials or innovative means of manipulating data (see "When the chips are down", left). But experts agree it will be many years before any provide sufficient improvement to head off the problems faced by computing.

A more radical approach may now be emerging. A growing number of researchers are revisiting Landauer's calculations and using new tools to dramatically expand our understanding of how thermodynamics and computing interact. For Jim Crutchfield at the University of California, Davis, computing's situation has parallels with the industrial revolution. In the 18th and 19th centuries, engines and pumps were built to convert heat into mechanical energy long before physicists formalised the principles of thermodynamics. When those principles were better understood, the gains in efficiency and power were astonishing.

"We're in the information age and we're kind of in the same conceptual situation," says Crutchfield. "The general claim is that if we understand these trade-offs, we're going to be able to design computers that are three or four orders of magnitude more energy-efficient."

The opportunity arises from what Landauer's work left out. For all its profundity, says David Wolpert at the Santa Fe Institute in New Mexico, it could only establish a maximum efficiency, not set out a road map to getting there. In part, that was due to the limited mathematical tools available at the time. They could only describe systems in equilibrium, where no energy enters or leaves, which is a massive oversimplification. "Computational systems are, if nothing else, extraordinarily non-equilibrium," says Wolpert. They are in

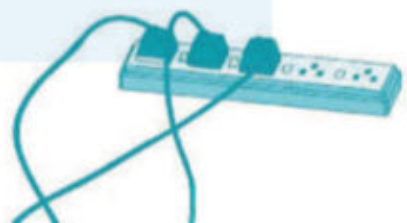
When the chips are down

All modern computers encode information the same way. They all use transistors that act as binary switches to control the flow of electrical current. Keeping these components operating in a way that allows us to reliably distinguish between their on and off states takes a certain amount of electrical power, which leads to waste heat. This restricts how closely we can pack transistors on computer chips without serious overheating problems and limits energy-efficiency gains (see main story).

One way to solve the problem is to change the physical properties of the hardware involved. At present, all modern computing is built on silicon. Within this material, the minimum power required for transistors to work effectively is relatively high. Using new materials like germanium, carbon nanotubes, graphene or strange conductive-magnetic substances called ferroelectrics could help bring this down. There are also proposals to use a quantum effect known as quantum tunnelling to ease power requirements.

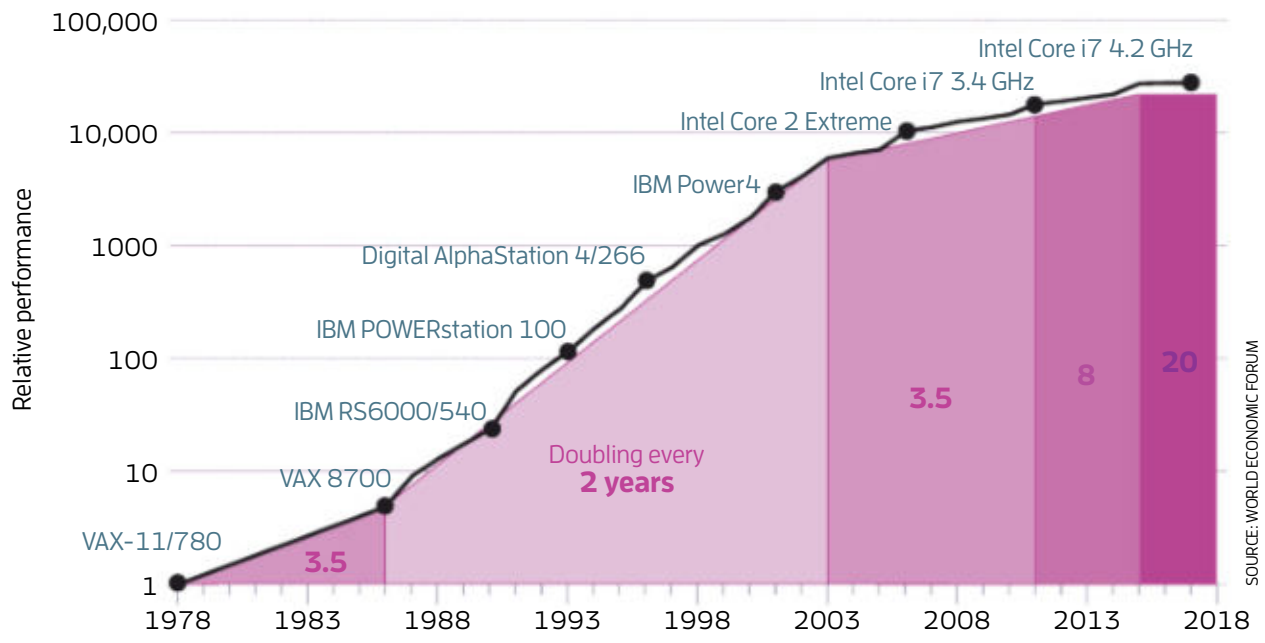
Even more exotic proposals involve changing how we use electrons in computer processors. Rather than relying on the charge of these particles to encode information, we could instead use other characteristics, like a quantum property they possess known as spin. Alternatively, we could bypass all these problems by replacing electronics with optical circuits that run on light.

None of these approaches are ready to replace silicon transistors yet, says Eli Yablonovitch at the University of California, Berkeley. It is possible that more radical alternatives are needed. Quantum computing, which uses the strange properties of quantum physics to manipulate information in entirely new ways, could drastically speed up cryptography, for example, while analogue computers that encode information continuously rather than as binary bits could prove useful for applications like artificial intelligence. At the moment, though, neither look set to replace general purpose computers.



Power slump

Improvements in computer chip performance appear to have hit a wall. Moore's law, which predicted performance would double every two years, hasn't held in over a decade and current trends indicate a paltry doubling every 20 years or worse



constant flux, and information and energy flow in and out of them all the time. In fact, almost nothing in the real world is in equilibrium, he says, something early computer pioneers were aware of but lacked the equations to describe.

There's another, equally important, property of equilibrium that the real world breaks. According to the laws of thermodynamics, an equilibrium system is in a state of perfect internal disorder – it has maximum entropy. But this is obviously not the case in everyday life, where the entropy of a system is constantly changing. Imagine pouring a jar of marbles down the stairs, for example. You know that all the marbles will eventually reach the bottom, but one or two might bounce back up some stairs on their way down. Averaged over the whole jar, this effect is insignificant, but on small distances and on short timescales, reversals of disorder are possible. The same dynamics play out at the nanoscale, a complexity that the traditional theory of thermodynamics couldn't predict or describe.

This began to change in the late 1990s, when physicist Christopher Jarzynski and chemist Gavin Crooks developed equations that allow us to precisely predict when such entropy reversals happen and how much energy non-equilibrium processes really use. These findings were groundbreaking, says Wolpert.

In recent years, there has been a growing realisation that this field could also help revolutionise computing, for example by charting the way to redesigning hardware as well as software to be more energy efficient using thermodynamic principles. "It's extraordinarily powerful," says Wolpert. "These tools they've developed can actually be used to go back and expand every single chapter in the computer science textbook." New equations built off the back of Crooks and Jarzynski's work can precisely calculate the energy required for a host of information processing tasks in much more realistic scenarios. Although Landauer's limit remains far off, that could open the door to enormous efficiency gains.

28 billion

the number of devices projected to be connected to the internet of things by 2025

Data centre efficiency is rising, but a crunch may be on the way

KULBHUSHAN SAXENA/EYEEM/GETTY IMAGES

These advances are uncovering new layers of complexity, says Wolpert. Minimising the energy your circuit uses requires complex trade-offs between things like speed, accuracy and physical layout. Wolpert has developed equations that can precisely calculate the thermodynamic cost of different circuit designs. While the ideas are still at an early stage, they could allow us to build significantly more efficient circuits from the ground up. "This is taking the exact same devices and simply wiring them a different way," he says.

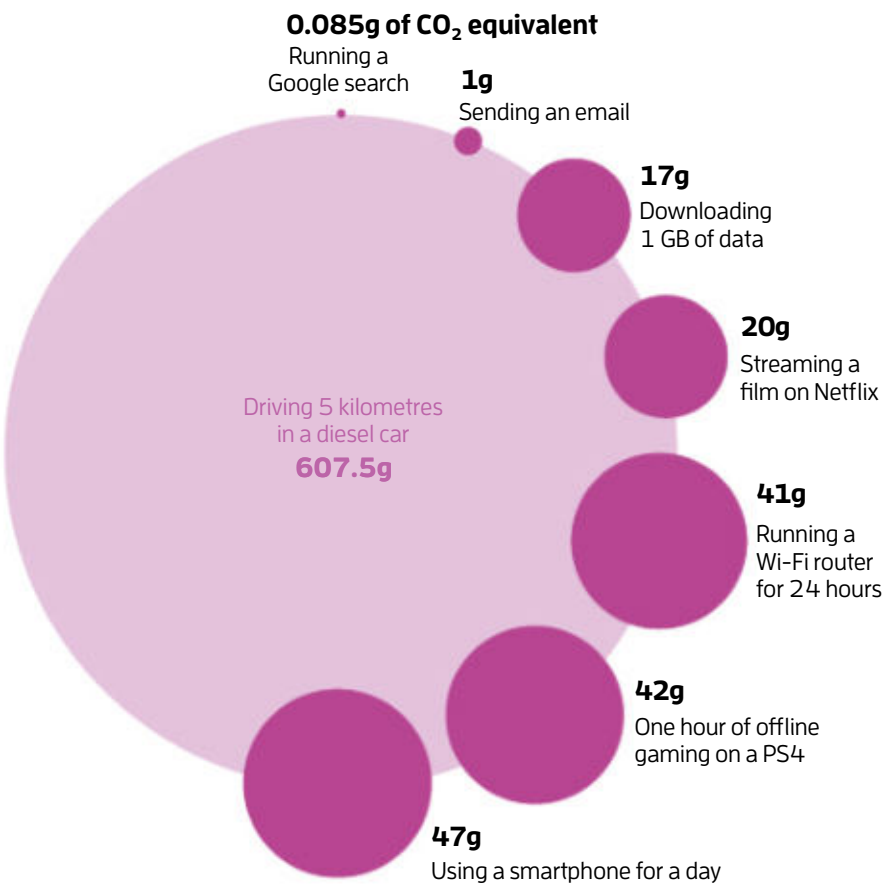
How far these ideas could take us is unclear, but proponents frequently point out that nature has already created a supercomputer that runs on a third of the energy your laptop uses – the human brain. This demonstrates that, at least in principle, new horizons are there to be unlocked. How nature achieves such efficiencies within the brain remains a mystery, but biology offers plenty of other examples of ultra-efficient information processing. Cells rely on a cascade of reactions to process chemical signals from the outside world, operating only about 50 times above Landauer's limit. The process by which enzymes copy DNA is similarly efficient, leading Microsoft to start investigating it as a potential computing technology.

"The most exciting perspective is whether living systems compute in ways we are absolutely not aware of," says Massimiliano Esposito at the University of Luxembourg. From what we know so far, that seems likely. Today's computers march to an internal clock, churning through sequential tasks to produce consistent outputs. That predictability is hard-won. On the tiny scale of transistors, everything from overheating to manufacturing defects can throw computations off. Engineers deal with this by building in wide margins of error and plenty of redundancy, but that, in turn, increases the energy required per bit.

Wasting energy would be a major disadvantage for living systems, says Esposito, and most information processing in biology appears to maximise efficiency at the ›

Digital footprint

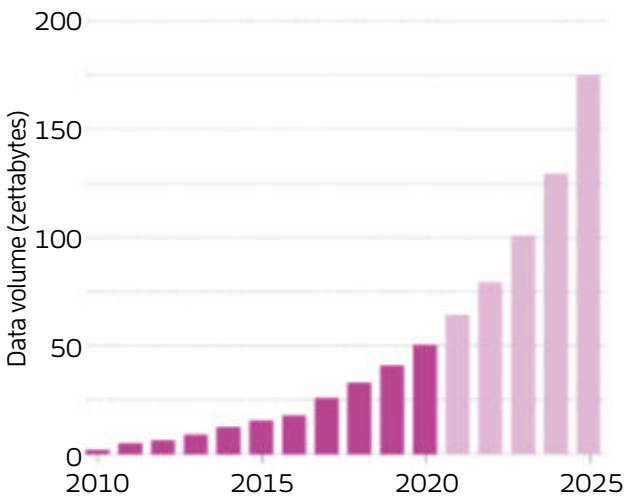
The energy required for the enormous global infrastructure built to process our data means that even everyday tasks have a carbon footprint



SOURCE: WORLD ECONOMIC FORUM

Data hungry

The volume of all our data is projected to balloon to 175 zettabytes (trillion gigabytes) by 2025



SOURCE: STATISTA.COM

> "Being able to mimic the slower, but ultra-low power computing seen in nature could be very attractive"

expense of other attributes like accuracy or speed. These are exactly the kinds of trade-offs non-equilibrium thermodynamics predicts.

As an example, most computers are governed by a single central processing unit that controls all other components. This centralisation is powerful, but means billions of instructions need to be fired off every second with incredible accuracy, at significant energy cost. By contrast, nature gives every cell in the body the power to independently implement the instructions contained in DNA, allowing them to perform in unison without the need for a conductor. That means that a process like DNA copying is able to trade speed and reliability for far greater efficiency. If we want to mimic nature's extreme efficiency, we may have to borrow some of these ideas.

Computing 2.0

What such a dramatic paradigm shift would look like in computing is hard to imagine, admits Crutchfield, but it holds vast promise. Despite its rapid growth, the internet of things is hamstrung by the need to power billions of small devices, often in locations that make them hard to recharge. In these circumstances, being able to mimic the slower – but ultra-low power – distributed computing seen in nature could be very attractive.

The hardware of the future is unlikely to stray far from today's chips and circuit boards, says Crutchfield, as that is the only approach we know how to scale. However, a hybrid approach combining traditional computing logic with components that harness thermodynamic effects is a likely starting point. The cryogenically cooled superconducting circuits used in quantum computers hold promise too, says Crutchfield, as they can also operate under conditions where non-equilibrium physics dominates. He has recently teamed up with applied physicists to test some of the field's predictions on these circuits, and says they could conceivably be scaled up for more sophisticated computing.

Not everyone is sold. The most glaring problem is that most work so far has dealt with theoretical circuits processing just a few bits of information. On the scale of today's silicon chips, though, these thermodynamic benefits would pale into insignificance compared with the waste energy they produce. "I'm all in favour of theory, but sometimes it just ignores reality," says Eli Yablonovitch at the University of California, Berkeley.

Bridging the divide between theory and engineering will take a lot of work from both sides, says Stephanie Forrest of Arizona State University. For one thing, the new mathematical tools that work on the level of bits rapidly become intractable once you start scaling them up. She believes that significant mathematical shortcuts will be needed before real-world computers can start benefiting from these breakthroughs.

Crutchfield agrees. That is why his research programme for the next decade will be dominated by putting the new ideas to the test. All the same, he wouldn't be surprised to see significant progress before then. "Maybe in about five years, people are going to appreciate what a huge revolution this has been," he says.

There are signs people are starting to appreciate it now. X, the so-called moonshot arm of tech giant Alphabet, recently hired Crooks to look into the potential applications of non-equilibrium thermodynamics. There are serious practical difficulties to putting these ideas to work, he says, but he doesn't see any fundamental barriers.

"It's not just a question of an incremental change in the energy dissipation of the things we've got now," says Crooks. "It would enable entirely new things." In a world awash with data, that could be just the lifeline we need. ■

Edd Gent is a freelance writer based in India. He tweets at @eddythegent

Ten years to save the world

Our actions in the coming decade will shape the future of life on Earth. We should feel excited about the opportunities this creates, Christiana Figueres and Tom Rivett-Carnac tell **Rowan Hooper**

JIT CHATTOPADHYAY/ZUMA PRESS/PA IMAGES

THE 2015 Paris Agreement marked a turning point in the fight to protect our planet against climate catastrophe. For the first time in more than 20 years of UN climate negotiations, all member states made a binding and universal pledge to reduce their carbon emissions as soon as possible, and to do their best to keep global warming well below 2°C while pursuing efforts to limit it to 1.5°C.

As executive secretary of the UN Framework Convention on Climate Change, Christiana Figueres led these negotiations, supported by her political advisor and strategist at the UN, Tom Rivett-Carnac. They later left the UN and set up Global Optimism, an organisation focused on bringing about environmental and social change by working with key campaigners, including Greta Thunberg, Al Gore and David Attenborough.

In their new book, *The Future We Choose: Surviving the climate crisis*, they present two scenarios for how Earth will look in 2050: one where we have failed to meet the targets set out in the Paris Agreement, the other where we have succeeded and now inhabit a carbon-neutral planet. They also outline how individuals can best encourage positive environmental change.

Rowan Hooper: Your book builds on the progress made during the Paris climate negotiations and sets a framework for what we can do as individuals to save the planet. What inspired you to write it now?

Tom Rivett-Carnac: We are facing probably the most consequential decade in human history. The Intergovernmental Panel on Climate Change (IPCC) has set out 196 scenarios ›

Listen to the big interview podcast
with Christiana Figueres and Tom Rivett-Carnac
newscientist.com/podcasts/

through which we can limit warming to 1.5°C, and none of them shows us peaking emissions later than this year. We can't prevaricate any longer. We need to start now, and by 2030 we need to be at half our current emissions. We need to bring all of ourselves to this moment and realise that this is a crisis moment, it's an emergency moment. We need to face it and then we need to act.

Christiana Figueres: We want to wake people up to the fact that they are implicitly already making a choice. It's an unconscious, perhaps an unwilled choice, but it is a choice. Of course, we can go on with business as usual, but that's going to end up in a world of destruction and suffering. Instead, we can and must make a conscious and intentional choice to change the way we live our daily lives and create a much better world.

At the beginning of the book, you paint a horrific picture of what the world could look like in 2050 if we continue with business as usual, with extreme flooding, rampant disease and malnutrition and the loss of coral reefs. Why was it important to show that?
CF: It was very intentional to present that world first, which is the business-as-usual consequence of what we're doing right now, and to put it in very stark terms. There is no exaggeration; it is completely consistent with what the science has been saying. The scary thing is that some of those things are occurring now, 30 years early, such as the forest fires in Australia. But we also wanted to contrast that world with one that is so much better, where we regenerated the soils, the land, the air – and where we have much more of a sharing culture. We thought it was important to describe the two realities we are choosing between.

TRC: It's a fascinating question, how you change the world. The fear of what's at stake has to play a role, but it also has to pivot into a gritty, determined sense of possibility and optimism, in which the knowledge of that fear takes you on a journey to where you are going to dig in, make a deep commitment to be part of the solution and play your role.

CF: And it's no anathema for us to do this as humans. If a parent is told that their child is sick because they have XYZ, the first thing that hits you as a parent is the consequence of that sickness. The second thing you do, is you say: "OK, if that's the challenge that I'm being faced with, now what do I do for my child?" Parents will do everything that is possible for that child to regain health. That is the kind of determination that we would like to unleash here. Our planet really is in danger and we have to unleash our collective stewardship, to be able to dig into all of our innovation, ingenuity and determination to bring the planet back into the safe zone and improve human life.

Is it right to place this responsibility on individuals, though?
TRC: This is the responsibility of everyone. If you look back at history, at the great transitional moments, they were moments where we had to dig deep and do everything we could as individuals, but also at every other level of society. We don't believe that individual actions are meaningless – far from it. But we also would argue that individuals can't do it on their own. Individuals need to engage with power structures, to engage with politics so that those leaders can take the steps that they need to move us forward as well.

CF: We aren't blaming individuals. Far from it. What we are saying is, "Wake up to the power that you have. Realise the agency that you have." It's quite remarkable when you think about the presence of humans on this planet: we have never had the agency, the technology or the capital that we have right now. We have never understood the policies better, never had the wherewithal or the impetus that we have right now to be able, over the next 10 years, to decide the future of many, many generations to come. It is an incredible responsibility and we can't be blind about it.

And yet, despite a big rise in social pressure, through Greta Thunberg and Extinction Rebellion, for example, we still haven't reduced emissions. Why not?
TRC: The relationship between civil engagement and political change is non-linear.

JIMENA MATEO

IVAN WEISS

Christiana Figueres was executive secretary of the UN Climate Change Convention, where Tom Rivett-Carnac was her senior strategy advisor

You push, and you push, and you push and nothing happens, then it suddenly shifts. Extinction Rebellion talks about this a lot. Once you reach about 3.5 per cent of a population that is actively engaging in a particular issue and pushing for it consciously, consistently and publicly, then there has never been a scenario where a group like that has failed to achieve its objectives, whether that's the women's suffrage or civil rights movements or the end of colonialism. There are very positive and encouraging early signs that the political winds are now moving in this direction. But like everything else on climate, they aren't moving fast enough. We need to accelerate them.

Christiana, you are famously optimistic. How did you feel when the newly-elected US President Donald Trump announced in the summer of 2017 that he was pulling his nation out of the Paris Agreement?
CF: I listened to his speech and was shocked that the leader of the world's most powerful country could be so misinformed about something so consequential. However, the US economy hasn't followed that lead. From a political perspective, the US will pull out of the Paris Agreement in November of this year, but its economy – which is made up of the states, the cities and the corporations – continues to decarbonise. I am concerned, actually, for the

MATTHEW ABBOTT/PANOS PICTURES

Left: Climate change is likely to lead to more wildfires, such as those that spread across Australia late last year Below: Saving the planet is a responsibility that all of us carry

SACHELLE BABBAR/ZUMA PRESS/PA IMAGES

"An increasing number of people are waking up to the reality that we can create something completely different"

competitiveness of US industry, because it's very evident that China, India and other countries are clearly investing in the new technologies that will dominate the future market in solar, wind, electric vehicles and batteries for charging those vehicles and supporting the electric grid. The US will not be able to keep up in that race.

President Trump has said he supports the Trillion Trees Initiative, which aims to protect and grow a trillion trees by 2050. Is that a good thing?
CF: We were all surprised that he came out with this statement. However, I am holding on to the possibility that a trillion trees will be planted by millions of people around the world. We must reduce emissions, but we must also increase the planet's capacity to absorb carbon from the air and to put carbon back into the soil where it belongs, improving its fertility and regreening Earth. Planting trees is a technology that has existed for thousands of years. It is quite cheap and very effective, so we should all get to it.

Tom, you spent some time in a forest in South-East Asia, living as a Buddhist monk. How does that feed into the philosophy that the two of you have put together?
TRC: One of the things I took away from that experience is this saying: "A bright mind is both the first step on the path and the final goal." The Buddha was very clear that to make progress on your spiritual path, you must approach your own internal state with a degree of curiosity, intrigue and gritty determination – and that you have to do it looking forward so that you can shine a light on where you go. I think that kind of brightness of mind, that sense of possibility and exploration is critical to what has been achieved so far. We saw that in Paris. Once the attitude of everybody shifted from "this is impossible, we're never going to do it" to "actually we can do something really remarkable here", it became the most fun party in town and everyone climbed on board – and then we really made progress.

If there was a single thing that you would like people to do, what would it be?
TRC: To realise the privilege of living at this moment. Future generations will look back and think, "My God, they lived at the fulcrum of this massive change." And they will either say "they were unable to deliver their responsibilities" or "they dug in and did something remarkable". I think bringing that consciousness to mind can turn this problem into something that we really feel engaged with.

CF: Related to that, I think an increasing number of people are waking up to the fun of this, to the reality that we can create something completely different, and that this could be the most exciting experiment in the history of humankind. My parents didn't have this choice, and my children won't have it either. It is those of us who are adults right now that have this choice to make in the next 10 years. That's it. How exciting is that? To wake up to our agency, to our power, to our creativity, to our innovation. So, what I would really love is for people to experience the joy of co-creating a better world. ■

Rowan Hooper is *New Scientist*'s podcast editor and co-presenter of *New Scientist Weekly*

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Send curriculum vitae and names and addresses of three references to Dr. Jonathan H. Jaggar, Maury Bronstein Endowed Professor of Physiology, Department of Physiology, University of Tennessee Health Science Center, 894 Union Avenue, Memphis, TN 38163, USA. **jjaggar@uthsc.edu**. https://www.uthsc.edu/physiology/faculty /jjaggar. php

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Marine Biological Laboratory

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The Ecosystems Center of the Marine Biological Laboratory (MBL) is hiring faculty at all levels to expand our program in coastal ecosystems ecology. Scientists with an interest in collaborative, interdisciplinary studies on coastal estuaries, bays, marshes, and/or coastal watersheds across the globe will be considered. Applicants from communities underrepresented in science, or with a strong history of service to these communities, are particularly encouraged. Candidates applying at the Associate or Senior level should demonstrate the potential to take a leadership role in the Plum Island Ecosystems Long-Term Ecological Research program (pie-lter.ecosystems.mbl.edu/) or the Semester in Environmental Science (mbl.edu/ses/). We seek candidates with diverse areas of research expertise, including, but not limited to, biogeochemistry and its controls, trophic interactions, ecological modeling, and community and ecosystem ecology. Top priority will be given to candidates demonstrating interest in conducting research within the broad context of global climate change and other anthropogenic influences on the coastal zone.

The Ecosystems Center (mbl.edu/ecosystems/) was founded four decades ago to investigate the structure and functioning of ecological systems and predict their responses to changing environmental conditions. The current faculty is highly collaborative, with strength in biogeochemistry, ecological modeling, microbial ecology, microbial dynamics, plant-soil interactions, coastal processes, and adaption to life on land (mbl.edu/ecosystems/faculty/). Ecosystems faculty also collaborate with other groups at MBL with expertise in molecular evolution, functional genomics, microbial diversity, developmental and regenerative biology, bioinformatics, and advanced imaging techniques. MBL's initiative in coastal ecosystems ecology complements other strategic initiatives at MBL involving microbiome research, the development of aquatic organisms as new research tools, and advanced imaging and image analysis. The MBL is an affiliate of the University of Chicago and an Equal Opportunity/Affirmative Action employer committed to diversity. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, disability, gender identity, sexual orientation or protected veteran status.

Qualifications:

Applicants must hold a Ph.D. (or equivalent advanced degree) in a relevant field. The successful candidate will demonstrate an interest in collaborative, interdisciplinary work, as well as a strong potential for establishing a vigorous extramurally supported research program that can complement existing areas of strength.

Applications should be submitted at **https://academicjobsonline.org/ajo/jobs/15843**

Applications received by March 15 will receive full consideration; however, applications will be accepted until the position is filled. Inquiries about the position should be directed to Dr. Anne Giblin, Chair of the Search Committee **(agiblin@mbl.edu).**

Northeastern University

Assistant/Associate/Full Teaching Professor - Electrical and Computer Engineering - Robotics

About the Opportunity:

The Department of Electrical and Computer Engineering at Northeastern University invites applications for Assistant/Associate/Full Teaching Professor with a focus on Robotics

Responsibilities:

Northeastern University's Department of Electrical & Computer Engineering seeks outstanding candidates for the position of Assistant/associate/full teaching professor with a focus on Robotics. This is a full-time, benefits-eligible, non-tenure-track position. Appointments are made on an annual 8-month basis, with salary commensurate with experience. The position of Assistant Teaching professor entails educational interaction with students in roles including, but not limited to, traditional instruction (lecture courses, lab courses), curriculum development, and student advising. The main responsibility of this position is teaching courses related to robotics, including kinematics, dynamics, and control of robots, design of microprocessor-based control systems, sensory devices, output actuators, numerical methods, state estimation, control, perception, localization and mapping, motion planning, and the ROS (Robotic Operating System) environment. Also expected to teach courses in embedded systems, digital logic design, computer organization and/or programming.

The annual teaching course load is six courses, with the potential for teaching more than one section of a course in the same semester, over Fall and Spring semesters. Courses may be at both the undergraduate and graduate levels.

Qualifications:

A PhD in Computer Engineering, Electrical Engineering, Computer Science, teaching experience, is required. Candidates should have demonstrated experience robotics and related subareas. At least 2 years' experience in teaching at the college/university level is recommended. Excellent written and oral communication skills are required. Industrial experience is desirable, but not required.

Application should include a cover letter, CV, teaching statement, 3 references. A sample syllabus from a previously taught class is optional but recommended.

Salary Grade: FAC

Additional Information:

Northeastern University is an equal opportunity employer, seeking to recruit and support a broadly diverse community of faculty and staff. Northeastern values and celebrates diversity in all its forms and strives to foster an inclusive culture built on respect that affirms inter-group relations and builds cohesion.

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To learn more about Northeastern University's commitment and support of diversity and inclusion, please see www.northeastern.edu/diversity

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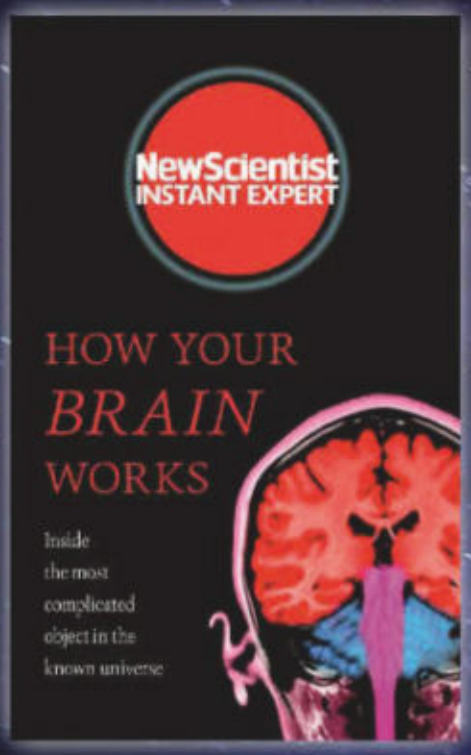

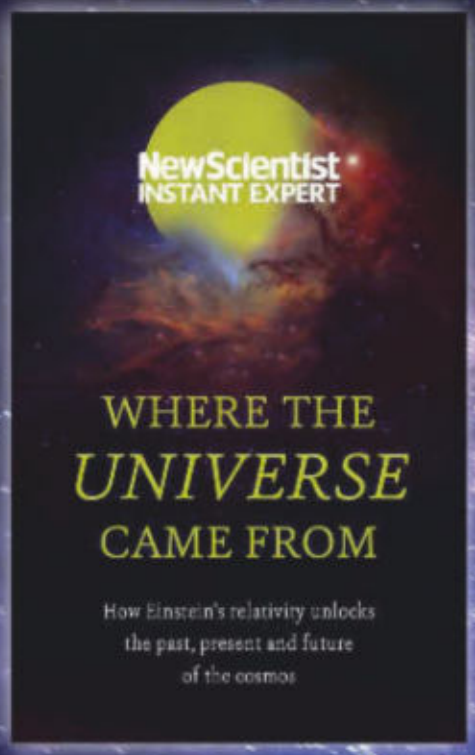

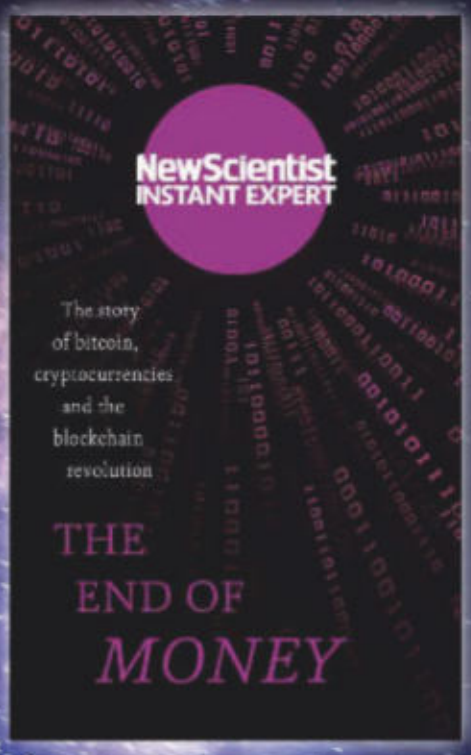

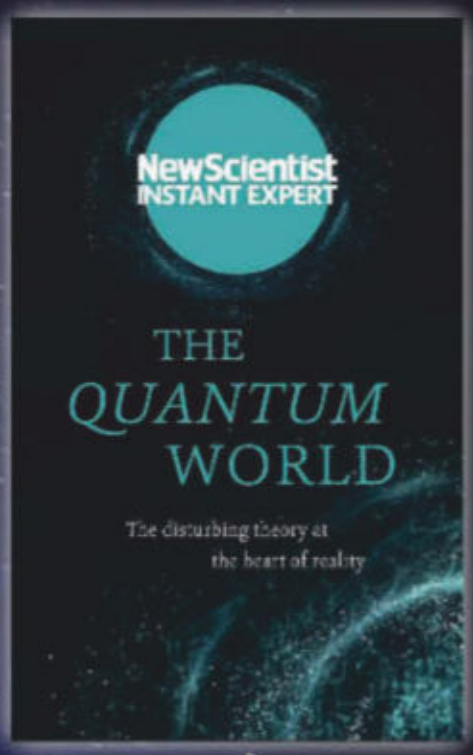

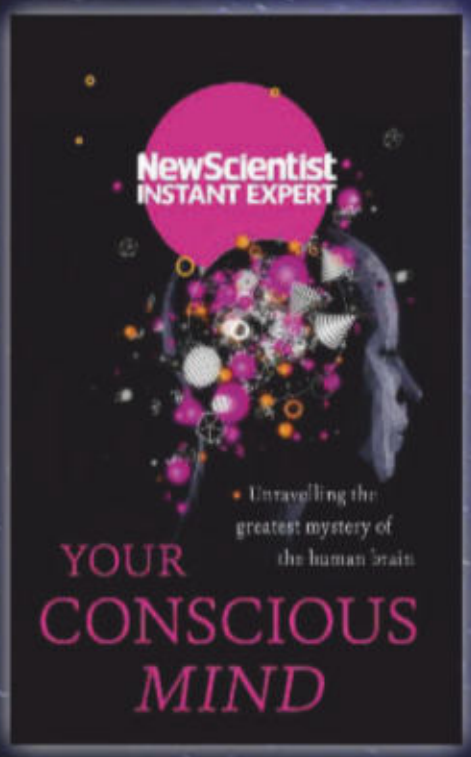

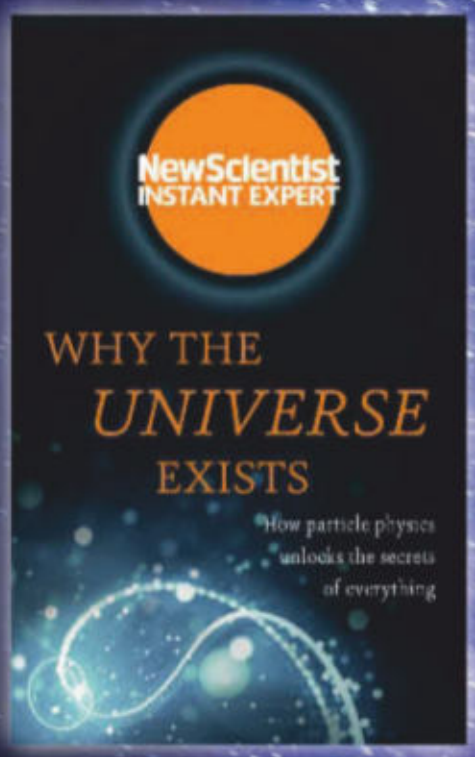

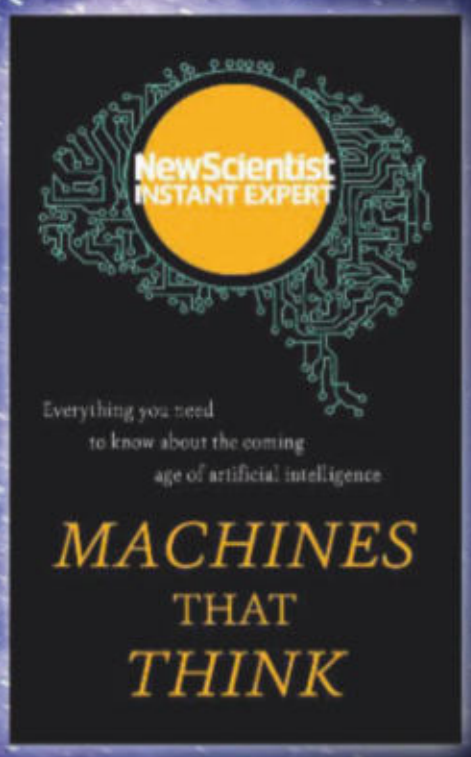

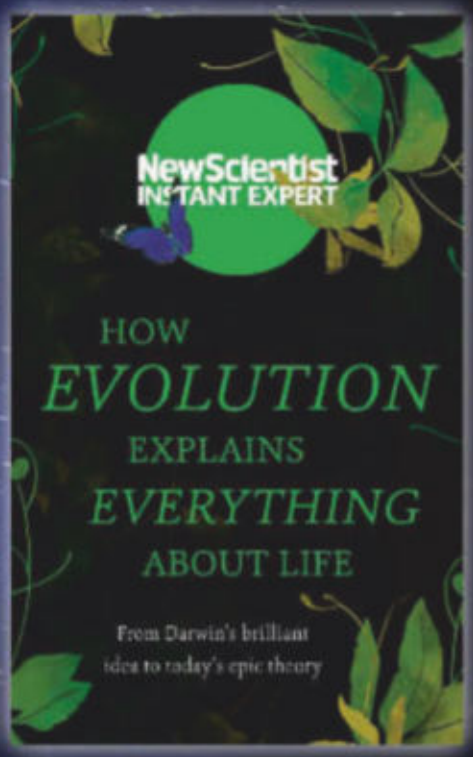

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Science of cooking **Week 11**

Bring out the best in garlic

Understand garlic's chemistry and you can add sweetness or fire to your food, says **Sam Wong**

Sam Wong is social media editor at *New Scientist*. Follow him @samwong1

What you need

Garlic
Vegetable oil
Salt
Lemon

For next week

Plain flour
Salt
Vegetable oil

Next week

Noodles: get to grips with gluten for silky, hand-pulled noodles

GARLIC can be big and fiery or soft and mellow. Understanding the chemistry of its flavour can help us amplify or tame it.

If you sniff a bulb of garlic, it doesn't have a strong smell. But if you bite into raw garlic, it will produce a pungent aroma and a burning sensation in your mouth. This is garlic's chemical defence, evolved to deter animals from eating the plant.

It is caused by a chemical called allicin, which activates the same pain-sensing receptors that respond to the capsaicin in chilli peppers. Allicin isn't present in garlic until its cells are damaged and stores containing an enzyme called alliinase break open. The enzyme acts on alliin, a derivative of the amino acid cysteine, to produce allicin.

Allicin has antibacterial and antifungal properties as it inhibits enzymes called cysteine proteases, which pathogens use to invade the tissues of their hosts. This is possibly why garlic has been touted as a medicine for thousands of years – Hippocrates recommended it for wound healing, for example.

Garlic becomes less fiery when you cook it, because alliinase is inactivated, stopping allicin production. Allicin is also unstable, quickly reacting to form other odorous compounds. Some of these can persist in the mouth for hours after eating garlic, giving rise to garlic breath. If this happens, eating an apple or salad can help, as enzymes found in many raw fruits and vegetables convert these compounds into odourless molecules.

VIRUSOWY/ALAMY

Science of cooking online
All projects are posted at newscientist.com/cooking Email: cooking@newscientist.com

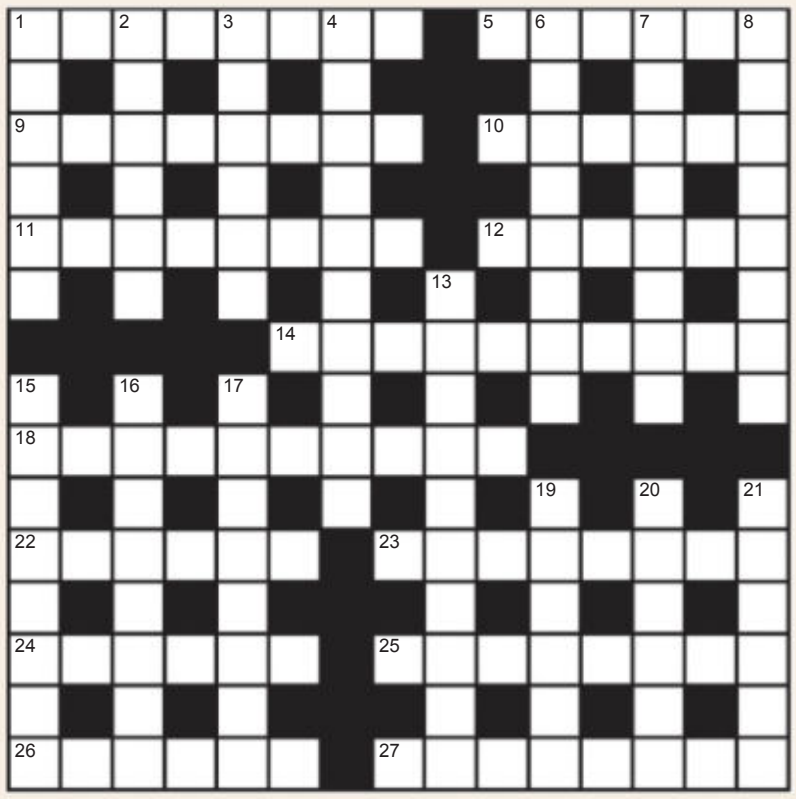
When we mince or chop garlic, we damage lots of cells. When we leave its cloves intact and cook them slowly, it becomes sweet and mellow instead. Here are two ways to prepare garlic that bring out different sides of its personality.

First, the fiery one: a Lebanese garlic sauce called toum. Peel two bulbs' worth of garlic (roughly 120 grams) and blend in a food processor with half a teaspoon of salt. With the blade still running, slowly add 125 millilitres of vegetable oil, then a tablespoon of lemon juice. Repeat until you have added 500 ml of oil and four tablespoons of lemon juice in total.

The result should be smooth and mayonnaise-like. Garlic contains emulsifiers that coat droplets of fat, allowing them to become suspended in water, but the oil must be added very slowly to make it work. If the emulsion breaks, add an egg white to the mixture and blend again. Toum is a perfect accompaniment to grilled meat, roasted vegetables or falafel.

Garlic confit is a great way to appreciate its mellower side. Peel two bulbs' worth of garlic and cover them with olive oil in a small saucepan. Cook over a very low heat for 45 minutes to an hour, until soft. Keep the cloves in the oil in a jar in the fridge. Mash them on toast, add to salads or eat them with pretty much anything.

Quick crossword #53 *Set by Richard Smyth*



ACROSS

1 May tree (8)
5 ___ *Around Us*, 1951 book by Rachel Carson (3,3)
9 Enveloped rock fragment (8)
10 Small flower (6)
11 1999 sci-fi film by David Cronenberg (8)
12 Otzi the ___, the Hauslabjoch mummy (6)
14 Low-growing plant in the genus *Cressa* (10)
18 Formation of a blood clot (10)
22 Move around an axis (6)
23 Extra sail on a square-rigged ship (8)
24 Long-fingered lemur (3-3)
25 Autostereogram (5,3)
26 Data obsessive (6)
27 Crewed NASA mission of 1970 (6,2)

DOWN

1 Thomas Henry ___, "Darwin's bulldog" (6)
2 Game theory scenario in which all participants profit (3-3)
3 Rock salt (6)
4 Photoreceptor cell (7,3)
6 Minimal surface described by Euler in 1774 (8)
7 String trimmer (8)
8 Th, Pa, U or Bk, perhaps (8)
13 US geologist and oceanic cartographer (5,5)
15 Nickname for the Strategic Defense Initiative (4,4)
16 Redness of the skin (8)
17 Violet quartz (8)
19 Use of spare urban land (6)
20 Improvise; cope with suboptimal conditions (4,2)
21 1992 sci-fi sequel directed by David Fincher (5,1)

Answers and the next cryptic crossword next week.

Quick quiz #42

1 What objects are classified by position on a Hertzsprung-Russell diagram?

2 Tarsiers, tiny primates in South-East Asian jungles, are notable for having relatively enormous what?

3 Paris, Marrakesh, Bonn, Katowice, Madrid... what city is next in this sequence?

4 A German scholar outlined 23 great unsolved problems of mathematics in a famous address at the Sorbonne in Paris in 1900. Who was he?

5 Which of his problems, involving the distribution of prime numbers, remained sufficiently great and unsolved a century later to be one of seven "Millennium Problems" announced by the Clay Mathematics Institute?

Answers below

Cryptic Crossword #26 *Answers*

ACROSS 1 Whoops, **4** IQ test, **9** Buffalo, **10** Aspic, **11** Algae, **13** Oak tree, **14** Jugular vein, **18** Timpani, **20** Niece, **21** Pinna, **22** Uploads, **24** Ersatz, **25** Cation

DOWN 1 Webcam, **2/17** Off season, **3** Plateau, **5** Quark, **6** Expertise, **7** Ticker, **8** Coronavirus, **12** Gourmands, **15** Vanilla, **16** Steppe, **19** Adapt, **23** Ali

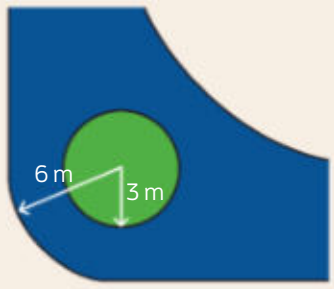
Quick quiz #42 *Answers*

1 Stars, placed on two axes according to their luminosity or magnitude, and their temperature or colour
2 Eyes. The only entirely carnivorous primates, they are nocturnal hunters with eyes that, at around 1.5 cm in diameter, are as big as their brains.
3 Glasgow. It will hold the 2020 annual UN climate change conference
4 David Hilbert
5 The Riemann hypothesis

Puzzle *set by Colin Beveridge*

#50 Crossing the river

Petal is on her way to a country fair, to sell some vintage kitchenware belonging to her good friend Gretel. As she walks along the River Biddle admiring the view, Petal trips on a pair of oars left carelessly on the bank. A valuable wrought-iron kettle flies out of her hand and lands on one of the river's many marshy islands.

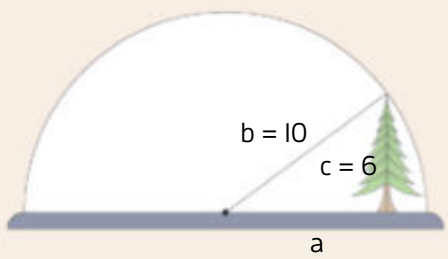


From the river bank to the island is 3 metres directly across, and though the oars are sturdy enough to walk on, they are just short of reaching over the water.

How can Petal reach the island with the paddles and save Gretel's metal kettle from its muddy peril?

Answer next week

#49 The tree in the snow globe *Solution*



$$a^2 + b^2 = c^2$$

The tree can move 8 centimetres from the centre. Viewed side-on, so the snow globe appears as a semicircle, imagine moving the tree as far as it can go. Line b, from the centre of the base of the globe to the top of the tree, is the radius of the semicircle: 10cm. The height of the tree and the distance it has moved form the other two sides of a right-angled triangle, so we can use Pythagoras' theorem to find the distance.

Our crosswords are now solvable online
Available at newscientist.com/crosswords

Thou shalt not troll

Social media can be a really unpleasant environment for anyone who isn't a bot, a troll or a GIF of a piano-playing cat. That's why Feedback welcomes any influencer who steps up and asks for their followers to adopt a kinder, gentler attitude towards their fellow users.

Take one Italian Twitter user – @Pontifex – who goes by the real-life name of Pope Francis.

He has been flying the flag recently for good behaviour online, for which we applaud him. In a recent Ash Wednesday address, for example, (sort of like a long, in-person TikTok routine) he urged the world's Catholics to give up social media trolling for Lent.

"We live in an atmosphere polluted by too much verbal violence, too many offensive and harmful words, which are amplified by the internet," he said, according to *Reuters*.

The period leading up to Easter, is therefore a time to give up "useless words", "gossip", "rumours", and "tittle-tattle", said Francis.

This is sound advice that Feedback may also try to follow for Lent. Although we suspect we may quickly run out of things to write. Come on, surely a little bit of tittle-tattle is OK?

No bad apples

If you want to pass for a good guy from a movie or TV show, then buy yourself an Apple product. Be it an iMac, AirPods or Apple Watch, the corporate giant's gizmos aren't just high-end technological tools, but proof positive that, if you were a character in a cinematic work of fiction, you would be on the side of the angels.

This advice comes courtesy of Rian Johnson, director of the hit film *Knives Out*, who revealed in a recent interview with *Vanity Fair* that Apple is very particular about product placement. In essence, he said, "bad guys cannot have iPhones on camera".

Apart from making the identity of murderers in detective movies ridiculously easy to guess ("swab that Samsung S8 for bloodstains", "get a search warrant for the guy using the Huawei"), the news represents a sad lack of imagination on the part of big brands.

After all, real-life villains buy phones too, don't they? For one of the world's biggest technology brands to turn its back on such a large and possibly affluent constituency seems like a profound strategic error. Bad eggs of the world: Feedback warmly welcomes your subscription dollars.

Bloody cancer

As Feedback recalls from bitter personal experience, working in public relations can be something of a mixed bag. Sure, you get the occasional freebie and glamorous drinks reception, but you also have to send emails to irritable journalists just waiting to make a fool of you at the drop of a hat.

On which note, we would like to thank a colleague for forwarding us the following email sent out by an anonymous representative from the PR industry: "I was wondering if you would be interested in covering the below announcement from my client, bloody cancer charity Anthony Nolan."

We all occasionally get frustrated at our employers, anonymous representative, but we really do hope they are treating you properly. Plus, look on the bright side – think of this valuable free publicity you have just secured for them!

All the tunes

Passing off other people's work as your own is a dirty business. That is why we invented the word plagiarism to describe it. But sometimes, reproduction can be unintentional.

Think of the world of music, where a half-remembered melody by one artist often forms the inspiration for a work by someone else. Deliberate theft, or accidental homage? Occasional rest note or a rip-off of John Cage's Zen-like silent audio spectacular *4'33"*?

As more and more music is produced by more and more people, it strikes Feedback as mathematically inevitable that certain combinations of notes will come up again and again. Even if not all of them are instantly hummable, whistleable or – Feedback's personal favourite – kazooable.

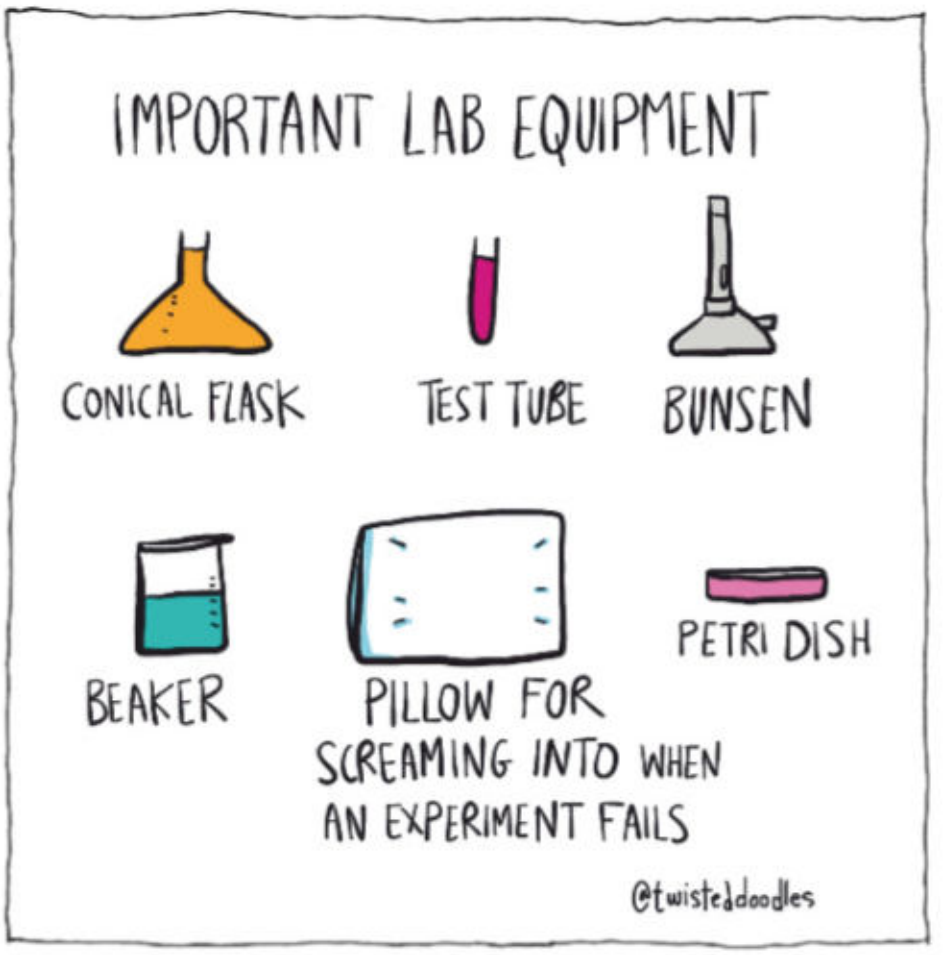
Most of the time, of course, nobody notices or indeed cares. But if the producer of tune A is a well-known creator of music with substantial record sales and an attentive legal team, and producer of tune B is a relative newcomer with a strangely familiar hit, then things can get unpleasant fast.

It was in an attempt to minimise such nastiness that Damien Riehl and Noah Rubin got involved. This week, the two released into the public domain an algorithmically generated dataset of every possible melody. Or, at least, the 68 billion or so melodies consisting of 8 notes in a particular octave starting from middle C and lasting for 12 beats. So, not every possible melody at all, really. But we digress.

The purpose of this act of generosity was to try to set a legal precedent. If all melodies are in the public domain, then none can be copyrighted, and if none can be copyrighted, then musicians should feel free to compose their oeuvre without fear of litigation. It is an interesting idea, but one that's unlikely to stand up in court.

Still, Feedback foresees ample scope for a similar wheeze in print. Bung together the 26 letters in all possible 860-word combinations and we won't have to work for a year. Brilliant. ■

Twisteddoodles *for New Scientist*



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Nuts for apples

A squirrel surprised us this autumn by picking apples from a tree and placing one each in hanging baskets around our garden, as well as putting two on top of the fence. Is this unusual behaviour for a squirrel?

James Stansfield
Winchester, Massachusetts, US
A few winters ago, I came across some stale ice cream cones at the back of a cupboard and put them out in the garden, in case any animals might want them. Soon after, I saw a squirrel placing them on shrubs all around the yard. As it was nearly Christmas, this seemed very appropriate. The squirrel carried each cone by holding one edge of the open top in its mouth, so it appeared to have a large, pointed snout.

Kay Bagon
Radlett, Hertfordshire, UK
I wonder whether this squirrel is just playing a game by picking apples from the tree and placing them in pots and on the fence.

This week, I watched with growing annoyance as several squirrels perched in our magnolia tree, pulled off the flower buds and merrily threw them on the ground. They then repeated the operation on our camellias.

The editor of this page, Julia Brown, writes:
We have looked into this, and the most likely answer is that the squirrel is caching the apples. Squirrels are known to store nuts by burying them, but they are omnivores that also eat apples, insects and much more besides.

We have often seen squirrels in London burying their hazelnuts in plant pots, so maybe the apple-caching squirrel has decided that hanging baskets are a good location for storing apples.

Contrary to popular belief, squirrels have good memories and well-developed strategies for food storage. A recent study by Mikel Delgado at the University of California, Davis, found that eastern fox squirrels didn't bury nuts randomly, but instead had a system for organising where they were buried based on the species of nut and where it was foraged from. And if they think another squirrel is watching them, they will even dig a hole and pretend to bury a nut, then cover over the hole and bury it somewhere else.

KEITH MORRIS/ALAMY

Why do some people sneeze many times in a row and others don't?

This week's new questions

Bless you **Rather than sneezing once or twice, some people do so again and again. My partner often sneezes 20 or 30 times in succession. Is this common, and is there any explanation?** ***Kate Wreglesworth****, Granada, Spain*

Great fleas... **How small does an animal or insect have to be before it can't have fleas, mites or lice?** ***Nina Dougall****, Malmsbury, Victoria, Australia*

Awful eaters

Foxes have the most repulsive smell, alive or dead. We often see dead foxes on our farm and they just decompose in situ. So, does anything eat foxes?

C. W. G. Angus
Wormit, Fife, UK
Some years ago, I noticed a dead fox lying in a fenced area by Lochan na Lairige in Perthshire. It looked as if it had recently fallen from the cliff above.

Sexton beetles were already burrowing into its fur. These beetles and their larvae are carnivores. I visited the spot about two months later and found no evidence of the fox.

Luce Gilmore
Cambridge, UK
Foxes are sometimes eaten by roadkill enthusiasts. The taste is said to be challenging. There are, by the way, vegans who are open to eating roadkill because these animals weren't deliberately killed. Waste not, want not!

Come clean

Is there a difference between shampoo and shower gel and, if so, what is it? (continued)

Stuart Sjalund
by email, no address supplied
I enjoyed the previous answers to this question, but they only talked about surfactants. There are other considerations.

One is pH. The pH of shampoo can vary, but I have found that the higher the pH, the stronger the cleaner. Sodium hydroxide, the workhorse of any shampoo or shower gel, helps control a product's pH level. While it is true that shampoo can be used as shower gel, the reverse can also be true, depending on the pH.

I make my own shampoo and shower gel very inexpensively. For shower gel, I use off-the-shelf soap and detergent – I am not interested in reinventing the wheel – plus sodium hydroxide, and this works very well. This results in almost complete body oil removal and a very high-quality body disinfectant. When I use this daily, deodorant sprays are no longer needed. My body oil is replenished continuously as is required, so there is no problem for me here. Please remember, though, that sodium hydroxide is extremely dangerous if mishandled. It is fine when properly diluted in water, but if in doubt, use less.

I also make shampoo using a soap and detergent amalgam with a pH of around 10. But there is no set recipe and you can vary the quantities of these to find a formulation that you like.

Victor Cheetham
Bolton, Greater Manchester, UK
On a related subject to this question, I wondered about soap. I am an ardent believer that soap is better than shower gel because, in addition to its surfactant properties, soap is also alkaline and will dissolve some dead skin, thus improving the cleansing process. Am I right or just deluded? ▮

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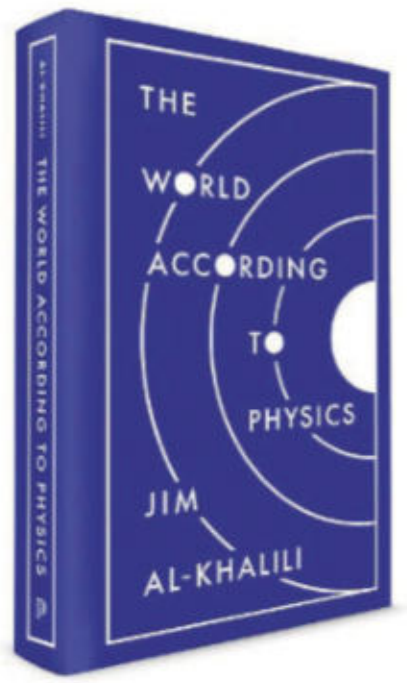

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The double-slit experiment has long been the cornerstone of quantum physics. Now **Urbasi Sinha**'s triple-slit variant could usher in an era of higher-dimensional quantum computing

So, what do you do?

I work with photons, investigating their use as building blocks for quantum technologies. These could revolutionise our lives due to their promise for exponential speed-ups in computing and unprecedented security in communications. One of our current projects involves quantum communication between two continents using a satellite.

The triple-slit experiment sounds interesting, what is it?

The double-slit experiment shows that photons act both as waves and as particles, but it also suggests that a single photon passes through both slits at the same time, a phenomenon called superposition. We devised a way to test if that was really happening with the triple-slit experiment. What we found suggests that we need to update our view of superposition and further experiments could potentially even question quantum mechanics. It also paves the way for higher dimensional quantum information science.

What do you mean by higher dimensional quantum information science?

Up to now, the focus has been on quantum bits, or qubits, which have two base states. We are working on higher dimensional systems such as qutrits, which have three base states. Triple slits provide a natural system wherein we have three modes of a single photon, forming a three-dimensional qutrit.

What would be different about a quantum computer using qutrits?

While everyone is excited about having 50 qubits together, the same outcome can be achieved with a smaller number of qutrits. This may help us develop quantum computers with greater power.

How has your field of study changed in the time you have been working in it?

Wow, a lot. When I first set up my lab in India in 2012, there was scepticism galore, both about quantum technologies and fundamental studies in quantum mechanics. Now, fundamental tests are the bedrock for modern quantum technologies and quantum computing is the in thing.

Did you have to overcome any particular challenges to get where you are today?

I sometimes wish I belonged to a different gender and had more grey hair. That can help in being considered seriously as well as with recognition. Having said that, why should I change? Let the world change its viewpoint!

If you could have a long conversation with any scientist, living or dead, who would it be?

One would be Marie Curie. I would ask her how she managed to be who she was and do what she did in spite of being a woman and living in a different era. I would also like to talk to Max Born. Our experiment was the first ever test of the Born rule, which predicts the probability of a photon's location after passing through three slits. I would like to know his opinion on our experiment.

You did the triple-slit experiment in a cornfield. Why?

Well, students get hungry! On a more serious note, the cornfield provided a natural anechoic chamber – in other words, one devoid of reflections from metal etc. – which is necessary for the precision experiment we performed. We also required a considerable amount of space for the experiment. We found out that corn is a great absorber of microwaves, too.

What scientific development do you hope to see in your lifetime?

A quantum computer that is powerful enough to break existing encryption systems, so our research on secure quantum communications becomes useful in my lifetime.

How useful will your skills be after the apocalypse?

Aha, you are assuming that my skills will outlive the apocalypse! Surely, that proves the point regarding their perceived usefulness? However, if practical quantum computing indeed becomes a reality by then, maybe we will find a way to survive the apocalypse simply through some mind-boggling simulations, which are currently difficult to fathom. Who knows? ■

"The results of the triple-slit experiment could question quantum mechanics itself"

Urbasi Sinha is a professor of quantum physics at the Raman Research Institute in Bangalore, India

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